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TRACE-ELEMENT GEOCHEMISTRY OF SANDSTONES HOSTING URANIUM-VANADIUM DEPOSITS IN THE LA SAL MOUNTAINS REGION OF UTAH AND COLORADO, U.S.A.

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TRACE-ELEMENT GEOCHEMISTRY OF SANDSTONES HOSTING URANIUM-VANADIUM DEPOSITS IN THE LA SAL MOUNTAINS REGION OF UTAH AND COLORADO, U.S.A.

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ABSTRACT

The hypothesis that hydrothermal solutions derived from the intrusion of the La Sal Mountains plutons redistributed uranium deposits in sandstones of the Salt Wash Member, Morrison Formation, was tested using statistical methods on trace element data for uraninite ore and barren sandstones. The concentrations of 46 trace elements, obtained via INAA, for a sample suite from 64 collection sites were examined. Specific attention was focused on the rare-earth element composition of the rocks, since such elements are useful as hydrothermal "tracers" as illustrated by McLennan and Taylor (1979, 1980) and Taylor and Fryer (1982). The statistical methods employed to examine selected trace element concentrations were linear regression analysis, comparison of means, and correlation coefficient analysis.

The following criteria were considered necessary to support the hypothesis: (a) selected trace element concentrations in the sandstones should show a spatial relationship to the La Sal Mountains, (b) the sandstones should exhibit a general enrichment of elements commonly associated with this particular hydrorothermal activity, (c) the sandstones should have a general depletion of the REE, indicating leaching of these elements by hydrothermal fluids and, (d) the ores should show a general depletion of the LREE and enrichment of the HREE relative to the host sandstones and an average sandstone model.

Linear-regression analysis on U, V, and As showed no obvious trend of composition varying systematically with distance away from the La Sal Mountains, as required by criterion (a). A comparison of means between the elements of the Salt Wash Member sandstones and an average model sandstone of Mason and Moore (1982) yielded possible enrichment in some elements such as U, V, As, Sc, and Co. However, there was a depletion of others such as Ta, Cu, Fe, and Ti. Thus, these results are inconclusive with respect to criterion (b). Correlation-coefficient analysis showed that the REE, Sc, and Th are primarily contained in clay minerals, probably hydromicas, at sites of cation exchange. Fe-Ti bearing phases are possible other sites of residence for these elements. REE concentrations of tabular and roll-front ores and the host sandstones were examined. Their values, normalized to chondritic meteorite values of Boynton (1983), were plotted versus atomic number. The results yielded similiar patterns between the ores, the host sandstones, and the average model sandstone. Thus the data also fail to satisfy criterion (c). Furthermore, criterion (d) was not fulfilled as enrichment of the HREE and depletion of the LREE, characteristic of hydrothermally deposited uranium ore, was not present in the ore samples of this study.

The results to date thus do not support the hypothesis that the uranium ore was redistributed by

hydrothermal solutions, possibly emanating from the intrusion of the La Sal Mountains plutons. Rather, the evidence appears to favor a syngenetic model of genesis for the ores, as proposed by Butler and Fischer (1978).

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INTRODUCTION

Purpose of Study

The purpose of this study is to determine if the emplacement of plutons in the La Sal Mountains, Utah, influenced the distribution of economically important uranium-vanadium deposits in the area. Specifically, were the plutons in some way responsible for the redistribution of uranium in the sandstones due to leaching by heated, groundwater solutions? To this end, sandstones and ore samples from the main ore-bearing horizon, the Salt Wash Member of the Morrison Formation, were analyzed for trace-element geochemistry, and in particular for rare-earth element compositions. It has previously been demonstrated (McLennan and Taylor, 1979, 1980; Taylor and Fryer, 1982) that the rare earths may be used as tracers in hydrothermal environments. Significant differences in the pattern to rare-earth element concentrations should occur between the sandstones and the ores, if ore deposition were from hydrothermal fluids leaching the sandstones.

The La Sal Mountains consist of a group of Tertiary diorite porphyry laccoliths and stocks. Uranium-vanadium deposits occur close to these mountains and seem to be concentrated in a discontinuous arc around them. If the intrusion of the La Sal Mountains had some influence on the distribution of the deposits, then this should be reflected in the elemental composition of both the source rocks and

the deposits themselves.

It was hypothesized that particular trace elements, especially the rare earths, might have a significant relationship to the plutons. Instrumental Neutron Activation Analysis (INAA) was utilized to determine the concentrations of the trace elements. The results were examined statistically to determine significant relationships between the trace elements of the sandstones and those of the ores.

Importance of Sandstone-Hosted Uranium Ores

A significant portion of United States production of uranium is derived from sandstone-hosted ores. Furthermore, more than 31% of the "reasonably assured western world resources" of uranium come from this country (Nash and others, 1981). Their use as a source of concentrated energy has led to uranium attaining the status of a strategic metal; hence much exploration and research have been conducted on these deposits. Although, a plethora of information on their geology and numerous hypotheses concerning the origin of the deposits have been generated by investigators with the U.S. Geological Survey and the Department of Energy, among numerous other workers, many questions concerning the origin and transport of uranium in these deposits await resolution. Evidence regarding the mechanisms of formation and genesis of these ores is inconclusive. Consequently, controversy over the

origin of the deposits remains.

Previous Ideas on the Origin of the Ores

In the United States most known uranium reserves are concentrated in Triassic and Jurassic fluvial sandstones and mudstones of the Colorado Plateau. The deposits generally are tabular in shape and in places are found as "rolls". Nash and others (1981) summarize four ideas on sources for the deposits as follows: a) related to meteoric or magmatically-derived hydrothermal solutions, b) caused by leaching of the host sandstones via ground water, c) caused by leaching of volcanic ash in the mudstones within the host sandstones, and d) due to leaching of granitic rocks in the vicinity of the host rocks. They concluded that the latter two processes probably are the most valid. On the other hand, McKelvey and others (1955) had earlier emphasized a definite hydrothermal link. Various other authors have repeatedly demonstrated that the host sandstones were leached. Thus, even though mechanisms a) and b) are not currently widely accepted by Nash and others (1981), the ideas remain worthy of consideration.

Kerr (1958) concluded that geologic and mineralogic evidence favors hydrothermal emplacement of the ores. Some of this evidence includes a) wall-rock alteration in sandstones, such as occurrence of chrome-mica clay along fractures and clay haloes at ore bodies, b) the presence of Se, Mo, As, Cu, K, V, Co, Cr, Pb, Zn, and S in the deposits

indicating a relation to igneous processes and, c) uranium mineralization in sandstones around volcanic breccia pipes and collapse features. The hydrothermal genesis is contrasted with leaching of the host sandstones or granitic rocks by circulating ground-water solutions. In some places, such as the occurrence of carnotite deposits (oxidized uranium ore), supergene or ground waters may play an important role. However, such waters are, generally, of low temperature. The presence of primary, unoxidized uranium ore (uraninite) below the water table cannot be accounted for by these waters. Kerr (1958) concluded that such ore was formed at temperatures above that of percolating ground waters. Most likely, deep, warm waters rich in uranium ions deposited ore at sites of reduction. Reduction at these sites were may result from the decay of organic matter. Indeed, much uranium is found replacing fossil plant material. Further, Gableman (1977) inferred that uranium-bearing solutions must have been quite saline, which again may be a link to hydrothermal solutions.

Kerr (1958) also found it difficult to accept that leaching of granitic rocks was an important source of uranium. He believed such rocks to be inadequate as a source for uranium. In addition, he concluded the fact that the deposits are distributed widely over the Colorado Plateau in great thicknesses of sedimentary strata makes granite a less likely source. Furthermore, Page (1960)

entirely discounted surface leaching of granite or sedimentary rocks. He cited as evidence the association of the uranium deposits to intrusive igneous bodies and structural features. Some of this evidence includes peculiar hydrothermal mineralogies and concentration of ore minerals around faults, folds and igneous intrusives. He concluded that hypogene solutions escaped from mafic to intermediate igneous rocks long before the magma began to solidify. Additionally, he noted that deep ground waters are chloride rich and that they could have mixed with juvenile waters before hypogene ore deposition was completed.

In another study, Weir and Puffet (1960) suggest that secondary copper ores (e.g. malachite, azurite) are related to uranium-vanadium mineralization in the Lisbon Valley area, Utah. Such copper ores are commonly associated with hydrothermal as well as supergene deposits.

Nininger and others (1960) established the idea of circulating ground water as the main transporting agent of uranium. The evidence they cited included (1) most deposits are in fluvial, continental sedimentary rocks, (2) fossil plant material is common, and (3) sulfides associated with the deposits are of bacterial origin. However, they implied that the ultimate source of the uranium may have been hydrothermal solutions. These solutions mingled with ground water upon introduction into

aquifers.

The ash-leach theory has also received considerable support. Granger and Waters (1953) made initial studies on the relation between uranium mineralization and devitrified volcanic ash (bentonite) in mudstones of the Salt Wash and Brushy Basin members of the Morrison Formation. They proposed that ground water leached uranium, vanadium and other mobile elements from the bentonitic clays. However, the fact that these clays adsorb rather than release uranium and vanadium into solution poses a problem. Further, Granger and Waters (1953) observed that the absence of blanket deposits of uranium, a likely result of ash leaching, negates simple leaching as a mechanism.

Butler and Fisher (1978) proposed the syngenetic deposition of uranium. In this theory, uranium was precipitated from circulating ground water while the sediments were being deposited. They indicated that the distribution of the deposits in the Uravan Mineral Belt, an arcuate distribution of uranium deposits east of the La Sal Mountains, occurs at a change in sediment size and type between coarse-grained deltaic deposits and finer-grained littoral sediments. Organic matter common to this zone is the main reducing agent for uranium. The fact that the uranium is found in the interstices of the sandstones and replaces organic matter makes this theory most attractive. One serious objection to this theory is the ages of the

uranium ores. According to published U-Pb age dates (Bergloff, 1970, Stieff and others, 1953) the deposits appear to have been emplaced in the sandstones at the end of the Cretaceous period or in the early Tertiary period whereas the age of the sandstones range from Triassic to Jurassic.

There still are problems in determining which processes prevailed. A possible resolution of the dilemma of the origin of the deposits could also lie in the notion that the ores may have formed by a combination of processes.

Choice of the Study Area

The Colorado Plateau has experienced a complex series of tectonic events which could have affected uranium dissolution, migration and precipiation in a variety of ways. One area in particular that has undergone considerable tectonism surrounds the La Sal Mountains. In addition to the intrusion of Tertiary diorite porphyry plutons of the La Sal Mountains, folding, faulting and uplift of surrounding strata have occurred at different times. Furthermore, it is especially significant that uranium deposits occur near the La Sal Mountains and seem to be zoned around the intrusions. This is most evident in the crescent-shaped configuration of the Uravan Mineral Belt. Thus it seems that both hydrothermal and ground-water solutions may have had some effect in the

distribution of the uranium deposits. Most deposits occur in sandstones of the Salt Wash Member of the Morrison Formation.

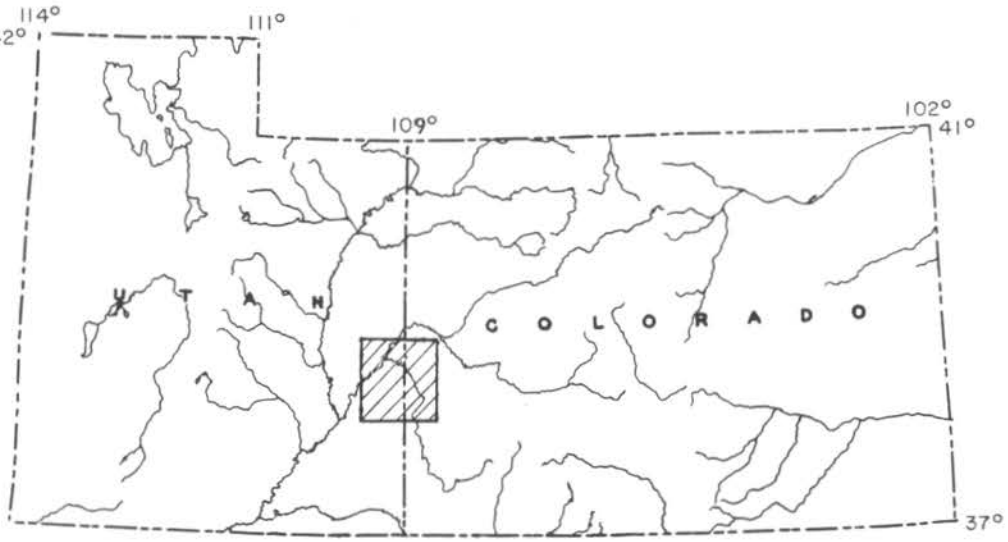
The area was chosen for three reasons: a) the frequency of the uranium deposits is high around the plutons, b) the deposits circle the mountains in a manner resembling peripheral zonation and c) exposures of sedimentary strata are quite good around the mountains.

LOCATION AND SETTING

The study area, the region around the La Sal Mountains, is in east-central Utah and west-central Colorado (Figure 1). Access to the area is via a number of paved and dirt roads in the vicinity of Moab, Utah. Moab, which was founded in 1875, is the largest town and now has a population of approximately 5,300. It is a center of tourism for the area, since Arches National Monument is just a few kilometers northwest of the town. In previous times (1945-1980), Moab experienced much activity as a result of uranium-vanadium mining in the area. Today, little of this activity occurs due to the depressed state of the mining industry. Potash is the major commodity currently mined, with cattle ranching the main agricultural pursuit.

Geographically, the area is in the eastern part of the Colorado Plateau in the tectonic province of the Paradox Fold and Fault Belt (Fig. 2). A number of deep, northwest-trending valleys transect the area, separating intervening highland mesas. The Colorado and Dolores Rivers are the major drainages in deep, steepwalled canyons. The highest terrain is the La Sal Mountains where the maximum elevation is 3874 meters on Mount Peale. Total relief is approximately 2700 meters. The vegetation is composed of sagebrush and grass in the valleys, juniper and brush on the mesas, and stands of pine and aspen in the mountains. A

A



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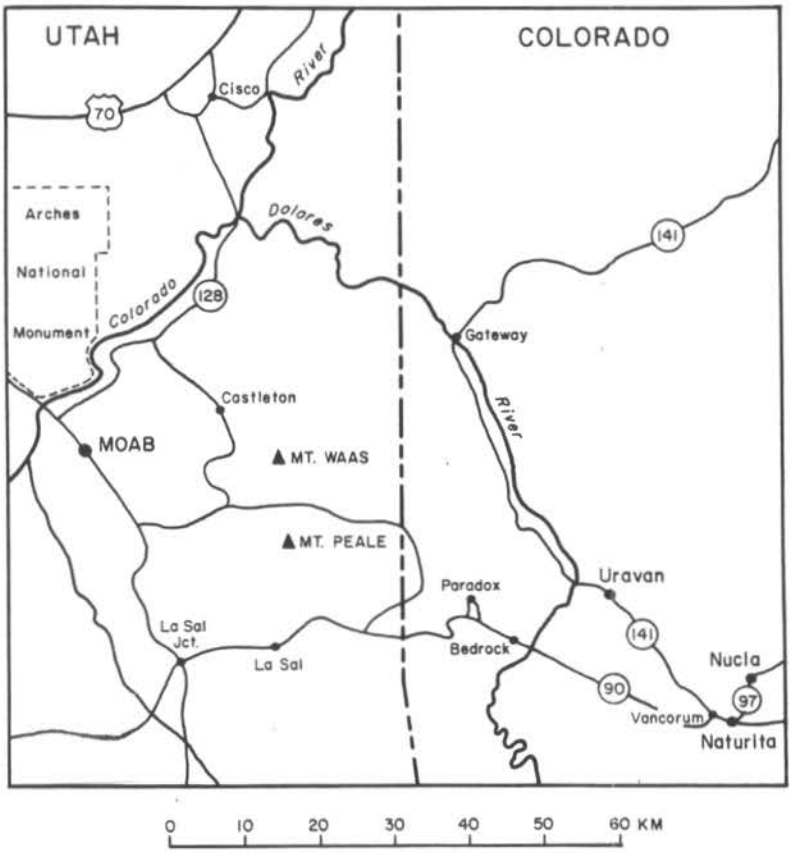


Figure 1. Location Map. Diagonally lined area in diagram A illustrates location of study area, diagram B.

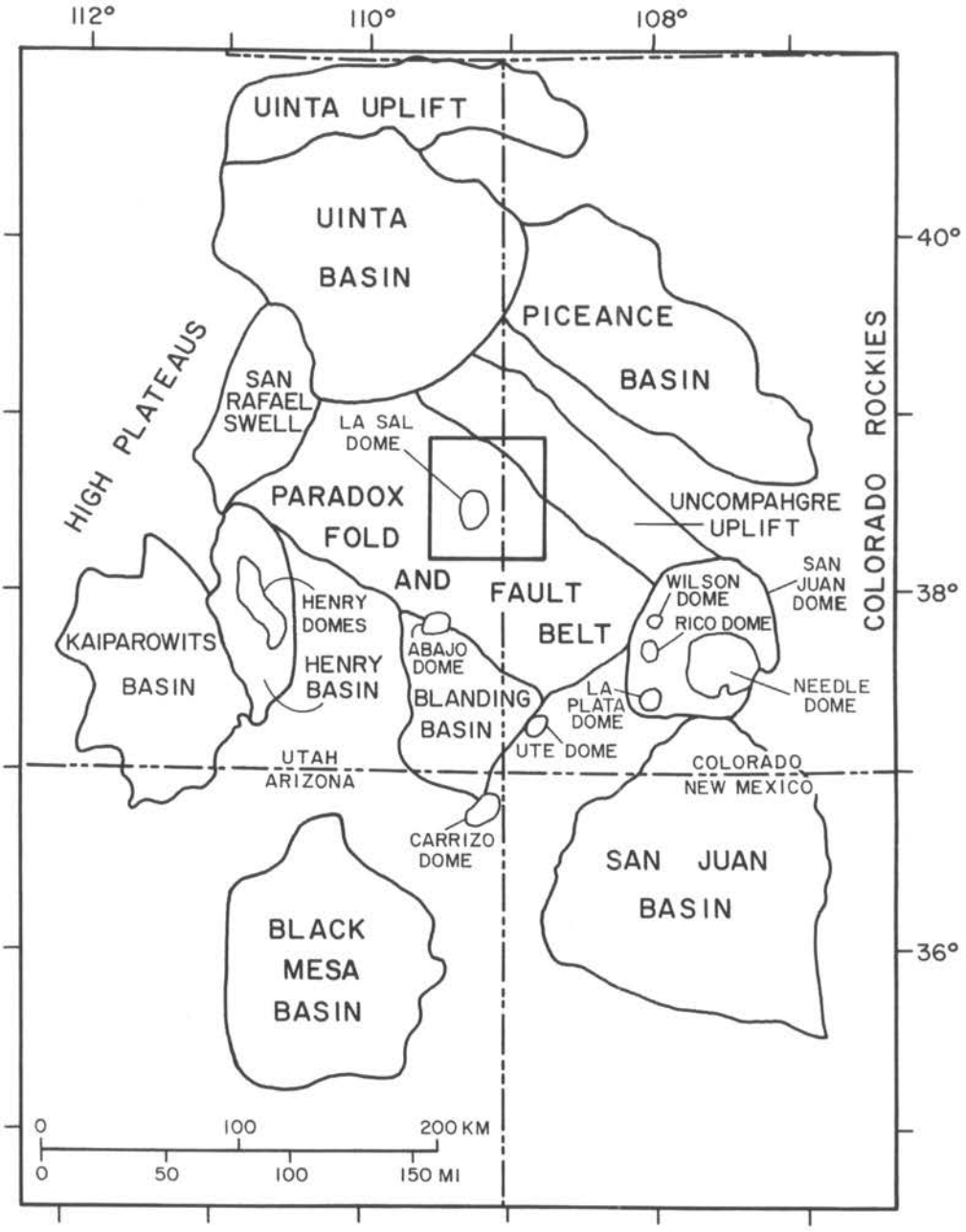


Figure 2. Index map of the study area showing its approximate location in the tectonic province of the Colorado Plateau. The rectangle shows the area of Figure 1B. Modified from Kelly, 1955.

few lakes occur on the east slope of the La Sals. Most of the precipitation occurs in summer, as thunderstorms in the mountains. Flash flooding may occur in the gorges and stream valleys. The mesas and large valleys are generally hot and dry in summer.

GEOLOGY OF THE LA SAL MOUNTAIN REGION

Stratigraphy.

Shoemaker (1954) and Shoemaker and others (1958) examined the strucuture for the area. Hunt (1958) focused on the structure and lithology of the La Sal Mountains. Williams (1964) compiled a geologic map of the area illustrating the relationship of uranium deposits to local structure. Carter and Gualtieri (1965) detailed the geology of the La Sal quadrangle. Detailed stratigraphy and examination of salt anticlines, particular to the region, was conducted by Cater (1970).

Most rocks of the study area are of Late Pennsylvanian to Late Cretaceous age. Quaternary and some Tertiary strata occur in the valleys, and on the flanks of the La Sal Mountains. The mountains are underlain by laccolithic intrusions of Tertiary age composed chiefly of diorite porphyry. Generally, the surrounding strata are continental red-bed deposits of sandstones, siltstones, shales and claystones and are horizontal with only local folding and faulting. Much of the folding is associated with the La Sal intrusions where nearby beds dip steeply in places. The faulting is generally confined to areas near intrusions where northwest-trending salt anticlines form broad linear valleys. Some minor folding is present in the salt anticlines.

Plate 1 is a generalized stratigraphic column for the

area. The oldest exposed sedimentary rocks appear in the salt anticlines and belong to the Pennsylvanian Hermosa Formation (Figure 3). This formation is composed of two members, the Lower Paradox Member and an upper unnamed member. The Paradox member consists of gypsum, shales, sandstones and limestones at the surface. Carter and Gualtieri (1965) reported that at depth the formation is composed of salt. In addition, they noted the thickness of this salt in Paradox Valley exceeds 3350 meters from borehole logs. The upper member crops out in Paradox and Sinbad valleys (Figure 3) and consists of arkose and limestone. It is thought that 548 meters of the member occurs in the La Sal area (Carter and Gualtieri, 1965, p. 5).

The Rico Formation occurs above the Hermosa and is believed to be Pennsylvanian to Permian in age. It is composed of fluvial sandstones and marine limestones (Williams, 1964). It crops out in Sinbad and Paradox valleys also.

The overlying Cutler Formation consists of interbedded sandstones and siltstones and is assigned a Permian age (Williams, 1964, Carter and Gualtieri, 1965). It is conformable on the Rico Formation.

The lowest Mesozoic strata comprise the Triassic Moenkopi Formation. In the study area, it is a thinly bedded, dark red-brown unit consisting of sandstones and

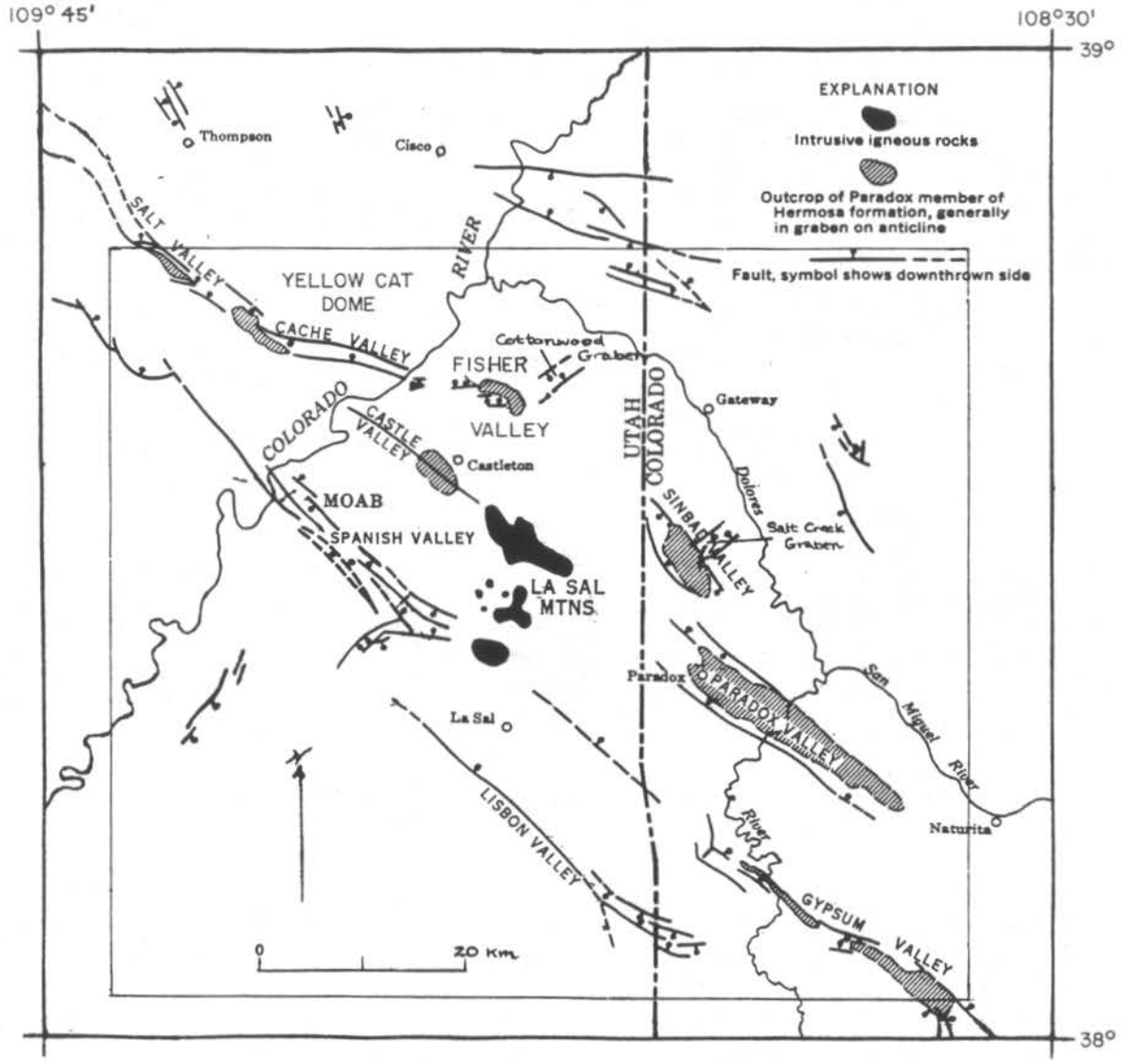


Figure 3. Index map of the study area showing structure. Outcrops of Hermosa Formation delineate the salt valleys. The included square frame shows extent of the study area. Modified from Hunt, 1958.

siltstones. Carter and Gualtieri (1965) estimate its thickness at 122 meters in the La Sal area.

The Chinle Formation is a thick sequence of red to brown shales, siltstones and sandstones resting unconformably on the Moenkopi, the Rico or the Cutler at various localities (Carter and Gualtieri, 1965). It is assigned a late Triassic age. It varies in thickness from 114 to 305 meters. The variable thickness is believed to result from movement of salt diapirs in the Triassic (Carter and Gualtieri, 1965). The formation is divided into two members, the Moss Back and Church Rock members. The Moss Back Member is known to contain economically productive amounts of uranium in the Lisbon Valley area, Utah (Butler and Fischer, 1978).

A series of Upper Triassic to Upper Jurassic rocks rests conformably on the Chinle Formation. The series comprises the Glen Canyon Group and contains the Wingate, Kayenta and Navajo Sandstone Formations. The Wingate Formation is a massive, cliff-forming, aeolian sandstone which is prominent in the river valleys and salt anticlines. The Kayenta Formation overlies the Wingate and and is composed of interbedded fluvial sandstones, shales and siltstones (Carter and Gualtieri, 1965). The Navajo Sandstone is present as a heavily cross-bedded, light-colored sandstone of aeolian nature. The three formations vary in thickness, especially in the area of

salt anticlines where thinning occurs. The thinning, again, seems to indicate movement of salt in the affected area at the time of deposition (Carter and Gualtieri, 1965). The Glen Canyon group attains a maximum thickness of 243 meters in the La Sal area.

The overlying Carmel Formation, the Entrada Sandstone Formation and the Summerville Formation comprise the sedimentary rocks of the San Rafael Group. They range from Middle Jurassic for the Carmel to Late Jurassic for the Summerville Formation. In the study area, only the Entrada and Summerville Formations are present. Carter and Gualtieri (1965) did not map the Carmel Formation as a separate unit because it is less than 20 meters thick. They included it in the Entrada. The Entrada Sandstone is divided into three members, the Dewey Bridge, Slick Rock and Moab Sandstone members. Generally, the formation consists of light-colored, cross-bedded sandstones. The Dewey Bridge and Moab Sandstone are thought to be subaqueously deposited whereas the Middle Slick Rock Member is aeolian in origin (Carter and Gualtieri, 1965). The Summerville Formation consists of shales and mudstones, thinly bedded and of variegated color. The San Rafael group has a maximum thickness of approximately 152 meters in the La Sal area (Carter and Gualtieri, 1965, Plate 2).

The Morrison Formation of Late Jurassic age consists of two members, the lower Salt Wash Member and the upper

Brushy Basin Member. The maximum thickness of the Morrison Formation is 213 meters in the area, with each member of approximately equal thickness(Carter and Gualtieri, 1965). The Salt Wash member is a sequence of sandstones and mudstones of fluvial origin. Plate 2 is a detailed stratigraphic section of this member as mapped by this writer. The locality of this section is approximately one-quarter mile east of the Firefly Mine, in San Juan County, Utah. The sandstones generally are fine- to coarse-grained, light-gray to buff-colored channel deposits. Cross bedding is abundant throughout. In these sandstone units well-known uranium deposits occur. Fossilized wood and dinosaur bones also occur in these beds (Carter and Gualtieri, 1965, p. 12). The mudstones are fine-grained and green to red in color. The green mudstones occur directly beneath the sandstones and form an irregular surface boundary (oxidation front?) with the red mudstones. Generally there are three to four beds or "rims" of sandstone sandwiched with the mudstones. Most of the uranium-vanadium deposits are in the upper part of the member.

The Brushy Basin Shale is a thick sequence of bright green, red, gray and purple siltstones, mudstones and shales; these characteristics delineate it from the Salt Wash Member. It is thought to be lacustrine. Granger and Waters (1953) determined that the dominant clay in the

Brushy Basin Member is bentonite, of volcanic origin. In the study area it crops out, in places, as bright green shaly slopes.

Lower Cretaceous rocks are represented by light-yellow to buff-colored, medium-grained sandstones and conglomerates of the Burro Canyon Formation. The rocks of this formation are quite resistant to erosion and often forms cliffs and mesa caps. Thickness reaches a maximum of 76 meters (Carter and Gualtieri, 1965).

The Dakota Sandstone Formation is an Upper Cretaceous unit that lies unconformably on the Burro Canyon Formation. It is composed of brown sandstones and conglomerates with interbedded shales, with a thickness not exceeding 61 meters (Carter and Gualtieri, 1965).

The Mancos Shale Formation of Late Cretaceous age varies in thickness up to a maximum of 366 meters (Carter and Gualtieri, 1965), and overlies the Dakota Sandstone. It appears as a dark, almost metallic gray sequence of very fissile shales and sandstones. In a few places coal seams occur.

The only Tertiary deposits in the study area are the Castle Valley and Geyser Creek Fanglomerates (Williams, 1964). They are composed chiefly of igneous rock clasts derived from the northern La Sals.

Quaternary sediments are of a wide variety and encompass conglomerates, alluvium, glacial deposits and

terrace gravels. Williams (1964), Cater (1970), and Carter and Gualtieri (1965) give detailed summaries of these deposits.

Igneous Rocks

The La Sal Mountains contain all the igneous rocks exposed in the study area. These mountains are eroded remnants of laccolithic intrusions consisting of diorite porphyry (Hunt, 1958). The outcrops have an elliptical shape of 24-32 kilometers in length and 11-16 kilometers in width, with maximum elevation of 3868 meters above sea level. Hunt (1958) divides the mountains into three distinct masses: North, Middle, and South Mountains. Each mass has a central stock and radiating laccoliths, with a number of sills and dikes also being present. In Castle Valley there occurs what seems to be an isolated small stock (as interpreted by this writer), although Hunt (1958) and Williams (1965) have mapped it as a laccolith. Generally, the La Sal Mountains igneous rocks have intruded salt anticlines trending northwest and thus it is inferred that the intrusions are younger than the anticlines. Based on geomorphic evidence Hunt (1956) ascribed a Late Cretaceous to Early Cretaceous age for the time of intrusion but Armstrong (1969) cites an age of 24 Ma. Hunt (1983) cites some problems in dating the intrusions from various mountain groups of the Colorado Plateau. The published dates which show intrusions ranging in age from

Late Cretaceous to Middle Tertiary (Hunt, 1983), lead to difficulty in interpreting the genesis of the mountains. If the intrusions are Late Cretaceous in age, then they may have formed during subsidence of the geosyncline developing in the area at that time (Hunt, 1983). On the other hand, if the intrusions are Middle Tertiary in age, then they may have formed as a result of the uplift of the Colorado Plateau (Hunt, 1983).

Structure

The study area (Figures 1 and 2) is part of the Paradox Basin, a fold and fault belt which is 320 kilometers long and approximately 160 kilometers wide. The basin is bordered on the northeast by the Uncompahgre Uplift, a northwest-trending terrane of Precambrian granitic and gneissic basement rock. To the north and west lie the Uinta Basin, the San Rafael Swell and the Henry Basin. The Black Mesa and San Juan Basins lie to the south (Figure 2).

Generally, the Paradox Basin is characterized by northwest-trending folds and faults, and in particular, it is noted for the number of salt-cored anticlines occurring within it. These give rise to the valleys in the area, namely the Paradox, Sinbad, Fisher, Castle, Salt, Gypsum and Cache (Figure 3). Normal faults border the sides of the valleys with the exception of Lisbon, Castle and Fisher Valleys; the latter two valleys exhibit very little

faulting (Williams, 1964). Lisbon Valley is unique in that the anticline is offset on the northeast side by a northwest-trending normal fault (Butler and Fischer, 1978). Formation of the valleys has resulted from solution of the salt with subsequent collapse of the overlying beds (Doelling, 1983). In the northwest part of the area there occurs a broad exposure of north-dipping Jurassic and Cretaceous strata known as the Yellow Cat Dome (Williams, 1964).

Diorite porphyry laccolithic intrusions (Hunt, 1958) are prominent features in the La Sal Mountains. Evidence of their intrusive nature is seen where sedimentary units meet the pluton, and are sharply upturned. A notable occurrence of this is at the north terminus of the mountains, near Castle Valley where beds of Paleozoic age crop out at a steep angle to the intrusion. Additionally, the La Sal Mountains diorites appear to intrude salt anticlines. Some evidence to this effect is Round Mountain, in Castle Valley, which is an isolated stock that Hunt (1958) called a laccolithic lobe. Also, the intrusions seem spatially related to the salt anticlines. This led Hunt (1958, p. 314) to postulate that the salt anticlines predated the intrusions and had some control on their shape.

Another major structural feature, the Uncompahgre Uplift, occurs directly east of the area. It is a

northwest-trending complex of gneisses, schists, granites, and pegmatites (Williams, 1964). The rocks occur in two groups: a younger intrusive group, composed of granites and pegmatites and an older group of schists and gneisses. Its importance to this study is that the Uncompahgre Uplift may have controlled sedimentation and deformation in the Paradox Basin. Indeed, the axes of the salt anticlines are oriented sub-parallel to this uplift.

Minor structural features present in the north part of the study area are Cache Valley, Cottonwood, and Salt Creek grabens (Figure 3). Cottonwood and Salt Creek grabens trend northeast whereas Cache Valley trends northwest.

GEOLOGIC HISTORY

The geological history of the Paradox Basin is complex. Basin subsidence influenced by regional tectonics (e.g. the Uncompahgre Uplift) and salt diapirism, probably initiated by movement along basement faults, controlled sedimentation in the area (Doelling, 1983). This was followed by Laramide intrusion with subsequent uplift and erosion.

Not much is known about Precambrian events except that regional metamorphism and batholith formation occurred, as evidenced in surface exposures of the Uncompahgre Plateau (Kelley, 1958). During Early Paleozoic time the region was stable. Kelley (1958) described the area as part of a foreland shelf of "the great Cordilleran geosyncline".

Beginning in Late Mississippian time or later, the foreland shelf began to sag. Throughout Pennsylvanian and Permian time subsidence continued and deposition of evaporites, limestones, and then clastic sediments occurred. The appearance of the clastic sediments, interbedded arkoses and evaporites, mark the first pulse of uplift of the Uncompahgre highland to the east (Shoemaker, 1954). A second pulse is evidenced by the deposition of Cutler Formation sediments in Late Pennsylvanian or Early Permian time. This episode of movement may have initiated rise of underlying salt, as evidenced by pinchouts of Cutler Formation beds in salt valleys (Shoemaker, 1954).

Compression of the ancestral Paradox Basin also occurred at this time (Kelley, 1958).

During Triassic through Late Jurassic time the Uncompahgre Plateau experienced further slight uplift along with ongoing rise of salt diapirs. A number of local angular unconformities between the Cutler, Moenkopi, and Chinle Formations provide some evidence for this (Shoemaker, 1954, Doelling, 1983). In Latest Jurassic time, salt movement ceased, temporarily. This is evidenced by Morrison Formation sediments lying directly on Paradox Formation rocks (Doelling, 1983). In Cretaceous time, the Paradox Basin again subsided, this time epeirogenically and strata of the Burro Canyon, Dakota and Mancos Formations formed (Kelley, 1958). In Late Cretaceous to Early Tertiary time, additional folding and faulting were initiated during the Laramide deformation. This deformation continued along lines of previously established structures (Kelley, 1958). In addition, Laramide orogenic events gave rise to the La Sal laccoliths, as well as the Abajo, Ute, and Henry plutons.

From Late Tertiary time to the present general uplift of the Plateau, the cutting of the river valleys and salt movement and/or collapse within the area have exposed the basinal beds and structures.

URANIUM DEPOSITS

Uranium-vanadium deposits in the study area occur largely within the Salt Wash Member of the Morrison Formation. However, Butler and Fischer (1978) note such economic deposits in the Chinle Formation in Lisbon Valley. Additionally, Carter and Gualtieri (1965) cite U-V deposits in a basal conglomerate of the Brushy Basin Member and Denis (1982) has worked on deposits in the Cutler Formation of Lisbon Valley. Small, relatively uneconomic deposits also occur in the Wingate and Entrada Sandstones (Carter and Gualtieri, 1965)

The deposits in the Salt Wash Member are generally confined to sandstones near the top of the member. These sandstones are interbedded with green and green-gray to red mudstones. The largest deposits occur within a particular, narrow stratigraphic horizon of sandstone approximately 12 meters in thickness and 30-45 meters above the base of the member. This horizon is commonly called the "third rim" (Carter and Gualtieri, 1965, p. 40).

The deposits have varying morphologies. Most are tabular in shape and are concentrated in pods of detrital plant remains ("trash pockets") or replacing fossilized wood (Chenoweth, 1983; Carter and Gualtieri, 1965; Wood and Lekas, 1958). Occasionally, deposits known as "roll-fronts" are observed. These deposits are bands of uranium minerals, principally uraninite, filling

interstitial spaces in the sandstones and cutting across bedding structures. Some deposits coat fracture surfaces. The deposits are widespread, being present on both the east and west sides of the La Sal Mountains. To the east, however, there occurs the elongate north-trending Uravan Mineral Belt where the deposits are more numerous (Butler and Fischer, 1978; Wood and Lekas, 1958). Figure 4 illustrates the location of this belt and the regional geology.

Weeks (1955) has studied the Colorado Plateau ores extensively and gives an account of their mineralogy. Carter and Gualtieri (1965) give a detailed summary of deposits in the La Sal Quadrangle. Chenoweth (1983) and Denis (1982) describe the mineralogy of particular deposits, while Butler and Fischer (1978) and Wood and Lekas (1958) give general summaries of the mineralogy.

The mineralogy of the deposits depends on whether they are unoxidized (reduced) or oxidized. In some instances both reduced and oxidized ores occur together. The unoxidized deposits occur below the water table and generally consist of the ore minerals Uraninite (UO_2) and Coffinite ($USiO_4$). Montroseite (VO(OH)) and Roscoelite ($K(V,Al)_2(AlSi_3O_{10})(OH)_2$), a vanadium hydromica, are the primary vanadium minerals. The minerals occur in pore spaces in the sandstones and replace detrital wood fragments. Commonly calcite cement is associated with

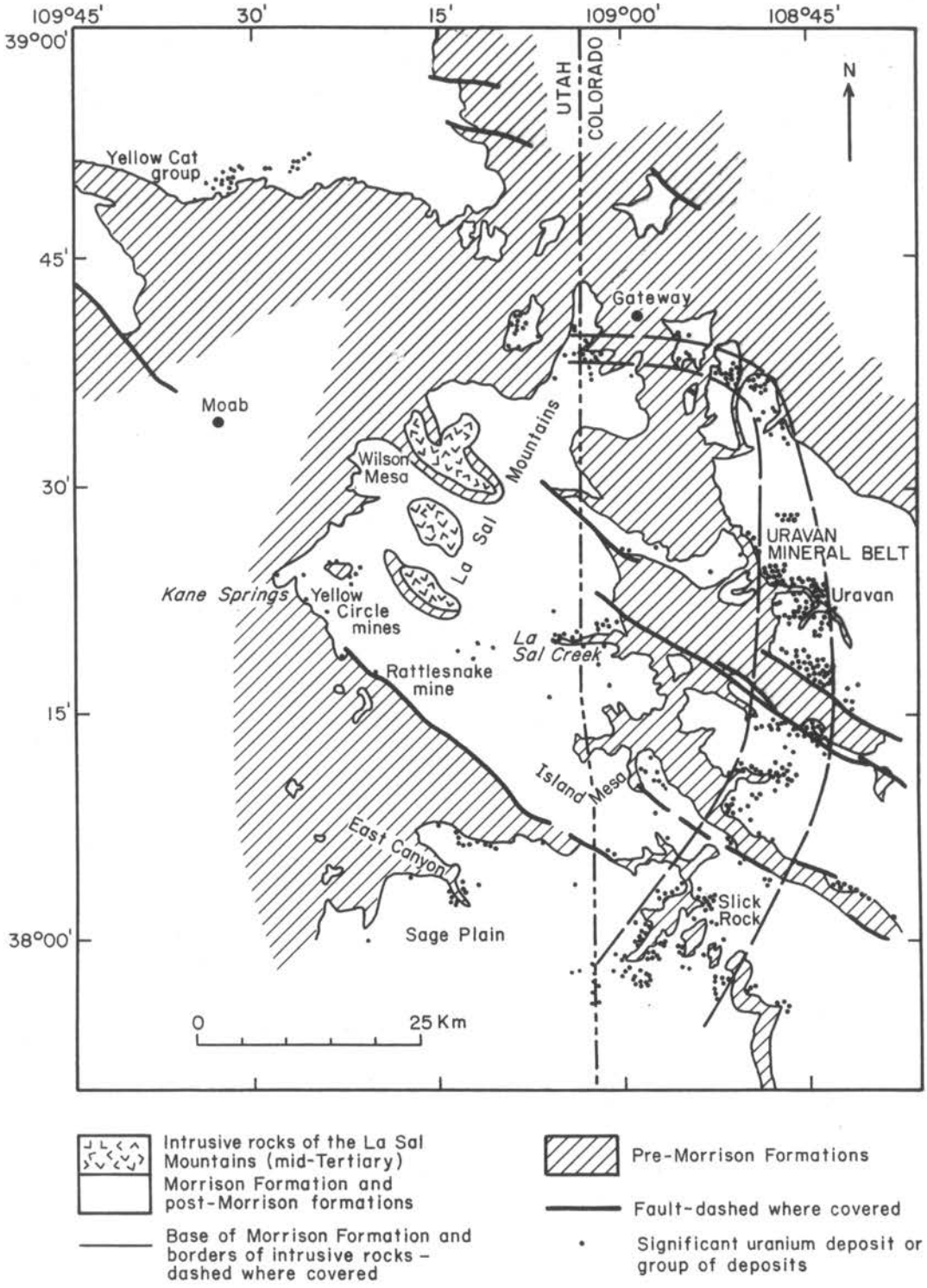


Figure 4. Generalized geologic map of part of the study area showing distribution and approximate location of uranium deposits. Modified from Butler and Fischer (1978).

uraninite in the wood.

Typical oxidized ores of uranium are Carnotite ($K_2(UO_2)_2(VO_4)_2 \cdot 7\text{-}10H_2O$), Tyuyamunite ($Ca(UO_2)_2(VO_4)_2 \cdot 7\text{-}10H_2O$), and Corvusite ($V_2O_4 \cdot 6V_2O_5 \cdot nH_2O$). These minerals form from the oxidation of uraninite. Generally, the minerals coat fractures, joints and mine walls, and fill pore spaces.

METHODS

Field Work

A geochemical reconnaissance around the La Sal Mountains was conducted for four weeks in June and July, 1984. Since a majority of the deposits occur in the Salt Wash Member of the Morrison Formation, this horizon was targeted for sampling. The sampling was confined to the stratigraphic bed of the Salt Wash in which the uranium deposits occur, namely the "third rim" sandstone.

A sampling plan was suggested to this writer and S. Shannon in a conversation with Alfred Miesch of the U.S. Geological Survey, Grand Junction Office. The sampling procedure suggested was designed to give the maximum coverage with the least expense and time while having the smallest amount of bias in sample selection. The procedure consisted of sampling at discrete intervals in traverses away from the La Sal Mountains. The sampling intervals were measured as horizontal distance (in kilometers) from the outer contact of the plutons with the country rock. The initial interval was arbitrarily chosen at 1.6 Km. As advised by Dr. Miesch, each subsequent outer sampling interval was determined by multiplying the preceding one by 1.5, yielding log-intervals of distance. For example, the first sampling interval of 1.6 km was multiplied by 1.5 to give the second interval of 2.4. This, in turn, was multiplied by 1.5 to give the third and so on. By doing

this, the chance of subjectively influencing the sample collection interval was decreased. The junction of a sampling interval and exposed outcrop defined a sample station. The mechanical process of locating the sample station consisted of overlaying pre-constructed circles, with a radius equal to the sampling interval desired, on a map of the area with the center of the circle located at the map boundary of the pluton and the country rock. Since the La Sals have a generally elliptical shape, so too did the sampling intervals. At each station two hand-sized sandstone samples were taken for geochemical analysis. In addition to the sandstones five ore samples from various mines in the La Sal Mountain area were also collected. Further, samples at points between the discrete intervals were collected in some areas. This was done to get additional, randomly selected samples for other statistical tests.

The collecting tool was a five pound sledge. The purpose in collecting two large samples with a heavy hammer was to reduce bias, that can result from differences in rock composition and sampling from one locality to another (Miesch, 1967). If a small pick were used then sampling would be restricted to portions of outcrop easier to obtain reducing the extent of collection surface and increaing the possibilty of variable bias.

Care was taken to sample unmineralized (barren)

sandstones near uranium deposits, since sampling mineralized sandstones will greatly bias the results for later study. Table A1 lists the sample stations and their intervals. Plate 3 is an index map of the sample stations.

Sample Preparation

Instrumental Neutron Activation Analysis (INAA) was employed to determine the concentration of specific trace elements. Sample preparation for INAA consisted of crushing selected sandstone and ore samples to sand size. The selected sandstone samples were representative for each station. The ore samples were uraninite from a few tabular and roll-front deposits (Table A1, Plate 3).

To reduce the chance of contamination by ferrous materials, a ceramic mortar and pestle were used. Care was taken to minimize contamination between samples by thoroughly cleaning the tools after each grinding. The ground material was placed in small plastic vials for long term storage.

INAA necessitates the use of specially designed vials (rabbits). These are made of "high-purity ethylene-butylene copolymer" (Minor and others, 1982), and measure 1.2 centimeters in diameter and 6.0 centimeters in length, and have a volume is 4 cubic centimeters. The ground sample material was placed in these rabbits and labeled. The labeled vials were sent to Los Alamos National Laboratory for processing. In order to minimize the

effects of instrumental drift, if any were to occur, the samples were processed in a random order.

INAA Analysis

Haskin (1980) reviewed the importance of neutron activation in geochemistry and Gibson and Jagam (1980) examined the techniques of sample processing, data handling and function of INAA.

Instrumental neutron activation analysis (INAA) has certain advantages over other methods for determining concentrations of trace elements. One advantage is the ease of sample preparation, since practically no pretreatment of samples is required prior to processing. Another advantage is the speed with which samples can be analyzed. Large numbers of samples can be processed in a relatively short time. The major advantage is the level of detection. Most trace substances can be measured at the parts per million level with good accuracy, in some cases even the parts per billion level can be achieved. Among the disadvantages of the method is that the equipment used, namely a nuclear reactor, is very expensive. Thus the cost of analyzing samples tends to be high in comparison to other methods.

For this study, the Omega West Reactor (OWR) at Los Alamos National Laboratory was utilized. Minor and others (1982) describe the operation of this reactor in detail. It was formerly employed in the Hydrogeochemical and Stream

Sediment Reconaissance (HSSR) program for National Uranium Resource Evaluation (NURE) of the U.S. Department of Energy. Table A2 lists the elements measured for this study. Samples contained in irradiation vials (rabbits) are sent into the reactor via a pneumatic system. When in the reactor core, the vials are held by clips and are rotated to give uniform irradiation. Following irradiation, the samples are assayed for their uranium content by delayed-neutron counting (DNC). The samples are then allowed to decay for 20 minutes. Following this, the samples are again counted using Ge(Li) gamma-ray detectors. After this the samples are irradiated a second time, stored overnight and the longer-lived gamma-ray activities counted. Data collection and reduction of gamma-ray spectra are loaded onto magnetic tape for later interpretation and manipulation.

Statistical Analysis

Reduction, manipulation and examination of the data required fast and efficient methods, so the Statistical Analysis System (SAS) package (SAS Institute, 1982) was chosen. Basically, SAS is a data handling and processing system developed by International Business Machines (IBM) for handling data of any kind. The advantage of SAS is that it can take any amount of data, in any form, and process it through any number of statistical methods and tests. Therefore, the need for writing long, tedious

programs to do the same is virtually eliminated. All that is required to process data is a basic working knowledge of the SAS language and procedures.

The hypothesis that trace element concentration is related to distance from the La Sal Mountains was tested utilizing SAS procedures. An initial test was to plot element concentration versus distance away from the La Sal Mountains for U, V, and As. The aim was to check whether these elements yielded a linear regression of concentration over the distance. The idea behind using linear regression is this. If the intrusion of the La Sal Mountains plutons did influence the distribution of uranium, then this should become evident in this test. A pattern of systematic variation (i.e. correlation) of elemental concentration versus distance should positively support the La Sal Mountains as an influencing factor. Conversely, no systematic variation (no correlation) will not support this idea. Further statistical tests focused on determining t-(Student's) test values and correlation coefficients for selected elements, in a comparison of means. That is, the average element concentration for the sample suite (this study) was compared with published average values for these elements in typical sandstones (Mason and Moore, 1982). These published values are taken to represent world-wide average, relatively unaltered, unmineralized sandstones.

The initial step in data reduction required the

replacing of all INAA values, showing concentrations below detection limits with an arbitrary value of 0.000001. This was done to prevent problems in calculating ratios, e.g. dividing by zero.

Next, the mean concentration and standard deviation (Table A3) were determined for two barren sandstone samples at each of the 59 stations (Table A1). The results were examined for any values which appeared to be anomalous with respect to uranium. Anomalous values are defined as those having concentrations two standard deviations or more above the mean (Koch and Link, 1971). The barren sandstone samples exhibiting anomalous concentrations in uranium were eliminated from the sample suite. The reason for excluding these samples is to minimize significant bias that may have been introduced while sampling (such as sampling near ore-grade material). The resulting "background" population was then treated statistically.

In plotting the concentrations of the elements U, V, and As (As was chosen since it is usually associated with these elements in the deposits) vs distance for a linear regression test, only the elements for stations within +-0.5 Km of a sampling interval were chosen. In this test, the stations that fell outside the sampling interval (+-0.5 Km) were deleted from the "background" population. The result was 39 of the 55 stations were left for plotting purposes.

The first step in a comparison of means required calculation of the mean, standard deviation and standard mean of error for the "background" population. Table A3 lists these quantities for the elements of this suite. In comparing the mean of one population (this suite) against the mean of the model (published values) it is assumed that both distributions are approximately normal. The next step was to apply the Students, or t, test. This statistic is designed to test the null hypothesis (H_0) that the mean of the sample population equals the mean of the model. The advantage of this test is that it may be applied to non-normal as well as normal populations. It is a two-tailed test, referring to the opposite ends of a normal distribution. The statistic is calculated by:

$$t = (|u_1 - u_0|)/(s/\sqrt{n})$$

where u_1 = the sample mean (this suite)

u_0 = population mean (published values)

s = the standard deviation

n = the sample size

A level of significance (α) at which the null hypothesis is rejected is specified in advance. For example, if it is decided to have a 5% level of significance then there is a 5% chance that the hypothesis will be rejected incorrectly. Most statisticians use a 2.5% level. A 1% level was used in this study, to minimize possible bias.

The calculated t value is compared against a tabulated t value (critical region) at the specified level of significance. If the calculated t value exceeds the tabulated t value then the null hypothesis is rejected and an alternate hypothesis (H_1) is accepted. The alternate hypothesis states that the sample mean of the distribution (this suite) differs significantly from the model mean (published values). It should be noted that in this work, a quantity known as degrees of freedom (ν) is used in comparing t values against tabulated values. This is the number of observations (n=55) minus the number of parameters determined. For example, in the t-test the number of parameters determined is just one (t) thus the degrees of freedom is n-1. The t values are tabulated according to the number of degrees of freedom.

The last statistic applied involved computing correlation coefficients (r) of all the elements against each other. The significance of this procedure is that it elucidates the degree of correlation between one variable (element) and another at some particular level of significance. If there is a perfect correlation then r will be unity. If there is no correlation then r will be zero, and negative or positive correlations may be determined. It is emphasized here that correlations do not necessarily imply relationships. That is, some elements may have a high correlation but show no obvious physical

relationship.

One advantage of this technique is that it determines, at a glance, multi-elemental pair-wise correlations. The disadvantage is that it involves voluminous calculations. SAS was especially useful in producing a correlation matrix for this suite of elements (Table A4). In calculating the values of Table A4 any elements that had concentrations below detectable INAA limits were set, by this writer, to a missing value (.) in SAS, rather than to 0.000001. This was done to prevent the possibility of obtaining specious correlation coefficients. Setting the values to 0.000001 was necessary for general statistical calculations but incorrect for correlation analysis. If values below detection limits were used then correlation coefficients would be calculated for unknown values of an element. However, setting the elements to missing values resulted, in some instances, in automatic deletion by SAS of a particular station in the calculations for the element considered. Therefore correlation coefficients of elements were calculated for less than 55 stations. This reduced the sample size and, therefore, the number of degrees of freedom. If the sample size is reduced to a value below n=30, significant departure from a normal distribution may begin to appear (Kennedy and Neville, 1976). On the other hand, this is partly compensated for by the reduced degrees of freedom. However, only a few elements (Cu, Mo, W, Se,

and Ta, see Table A4) had a population size of less than 30. For an r value to have significant correlation, it must equal or exceed the tabulated r (Kennedy and Neville, 1976) for a particular degree of freedom at a chosen level of significance (α=1%). Thus, reduced degrees of freedom will require higher calculated values of r to exceed higher tabulated values of r. In Table A4 the first numerical value in the column for each element-element block is the correlation coefficient and the second value, below it, is the number of stations where the element was present.

DISCUSSION OF RESULTS

Sample Population

The initial step required taking the mean and standard deviation of element concentrations for the 59 stations. "Anomalous" stations, those exhibiting concentrations of uranium greater than twice the standard deviation for this element in the sample suite, were eliminated from the suite. These stations, 3, 38, 44, and 46, showed uranium concentrations of 50.9, 30.2, 34.9, and 33.1 ppm, respectively. The remaining or "background" stations were well below the 2 standard deviation of 19 ppm, the maximum occurring at 12.8 ppm (Table A3).

Concentration of U, V, and As versus Distance from Plutons

For the test of linear regression of concentration versus distance, the following stations were eliminated from the "background" suite: 16, 24-30, 41, 47, 49, 55, and 56-59, since they fell outside the selected log-interval distances (+-0.5 km) of 1.6 km, 2.4 km, 3.6 km, 5.4 km, 8.2 km, 12.2 km, 18.3 km, 27.5 km, 41.3 km, and 62.0 km. Station 41, although it occurred within a log-interval, was eliminated because it exhibited anomalous uranium concentration relative to the entire "background" suite. The result was a much reduced sample population consisting of 39 stations. The U, V, and As concentrations were plotted for these stations. U and V were selected as target elements for a linear regression analysis. In

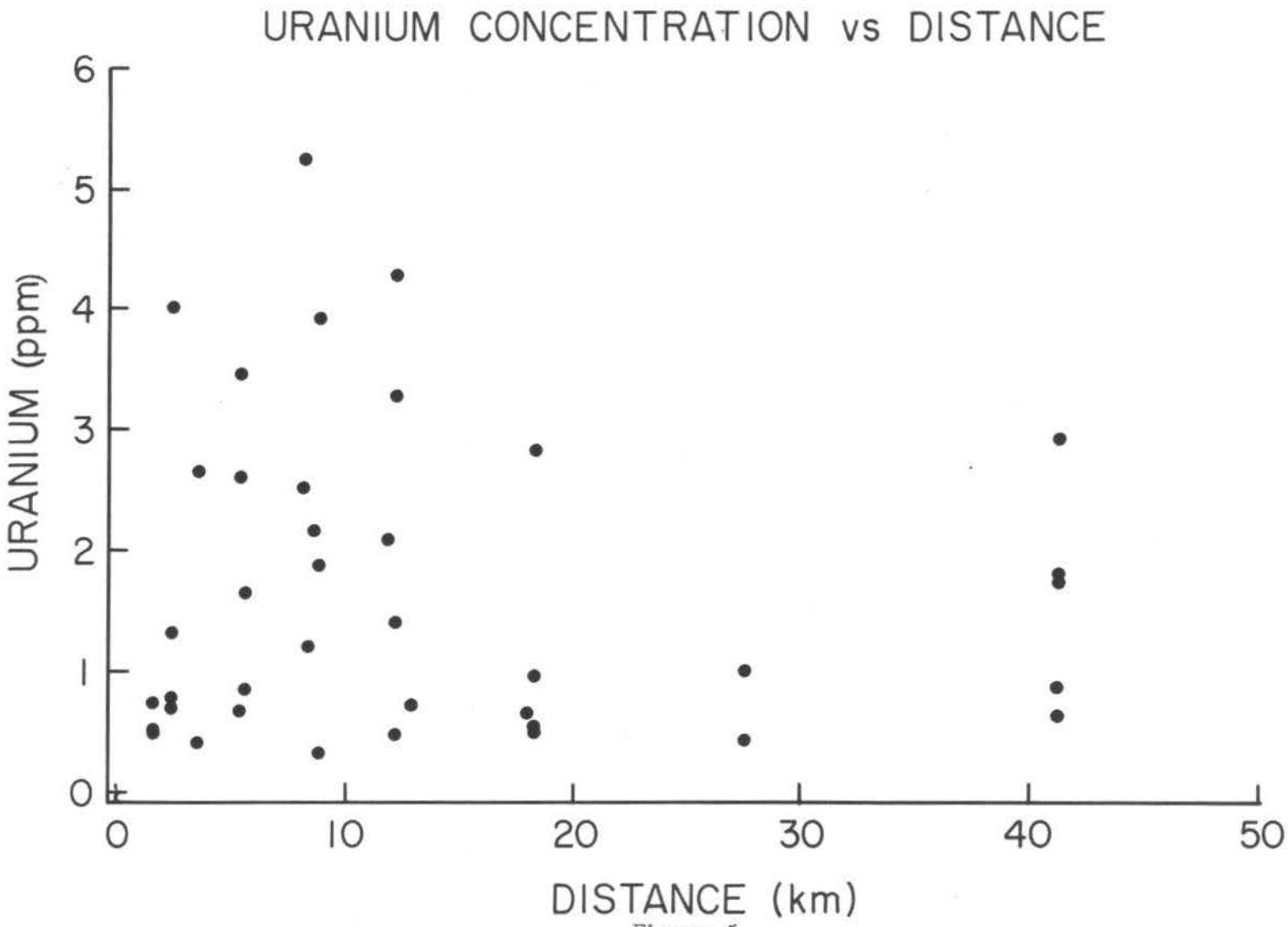
addition As was chosen, arbitrarily, as a further, independent check for linear regression of concentration versus distance. This element is known to occur as an accessory component to the uranium deposits in the La Sal Mountains area (Shoemaker and others, 1959).

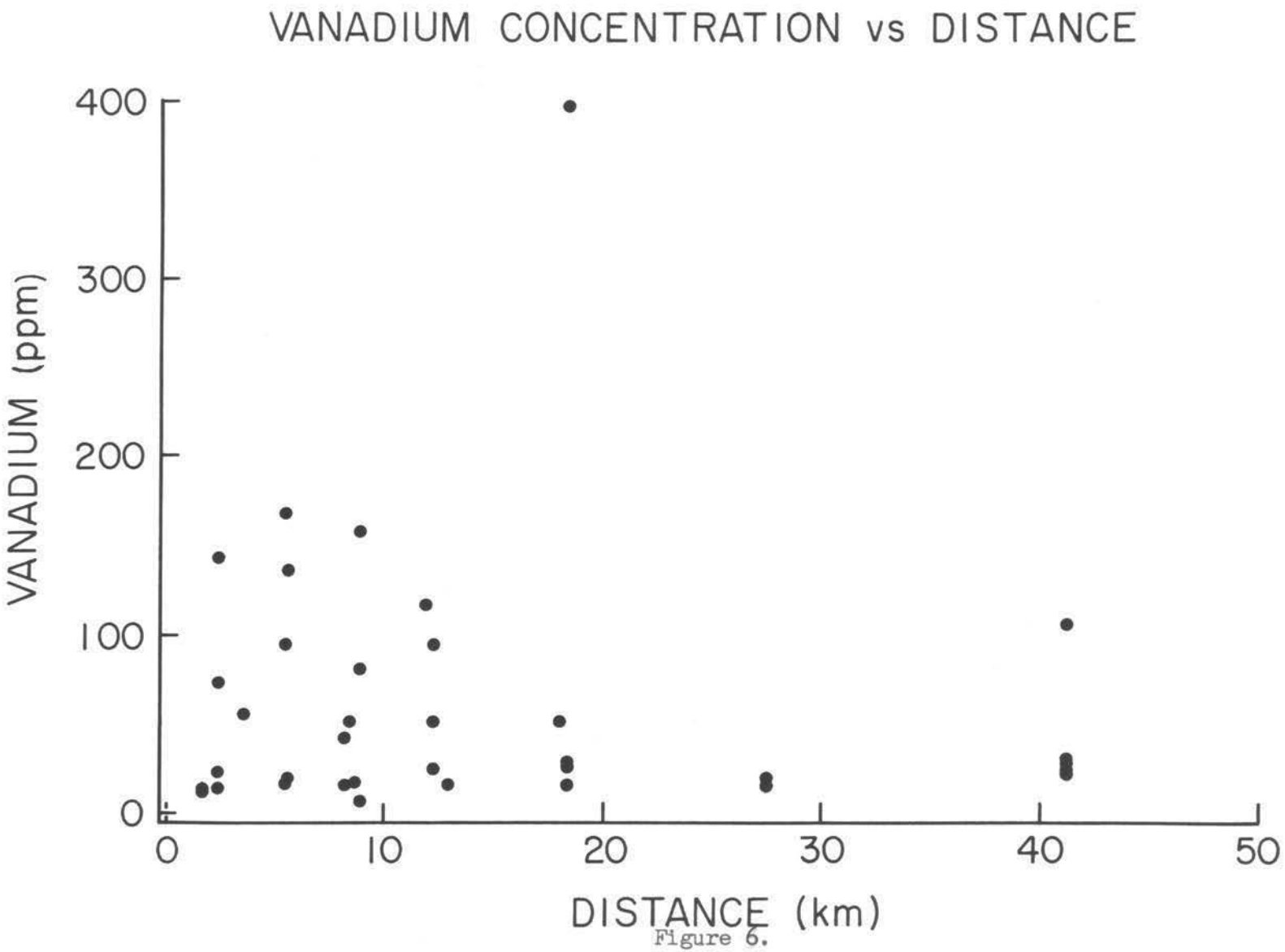
The hypothesis tested by linear regression analysis is that U,V and As concentration should vary systematically with distance away from the La Sal Mountains. If the intrusions were responsible for redistribution of the uranium deposits, then as one proceeds away from the La Sals down the paleothermal gradient there should be a gradual increase in U, V, and As with an abrupt decrease at some distance, signifying the outer limit of ore deposition; indicating possible zonation in the current distribution of the deposits due to the intrusion of the La Sal plutons.

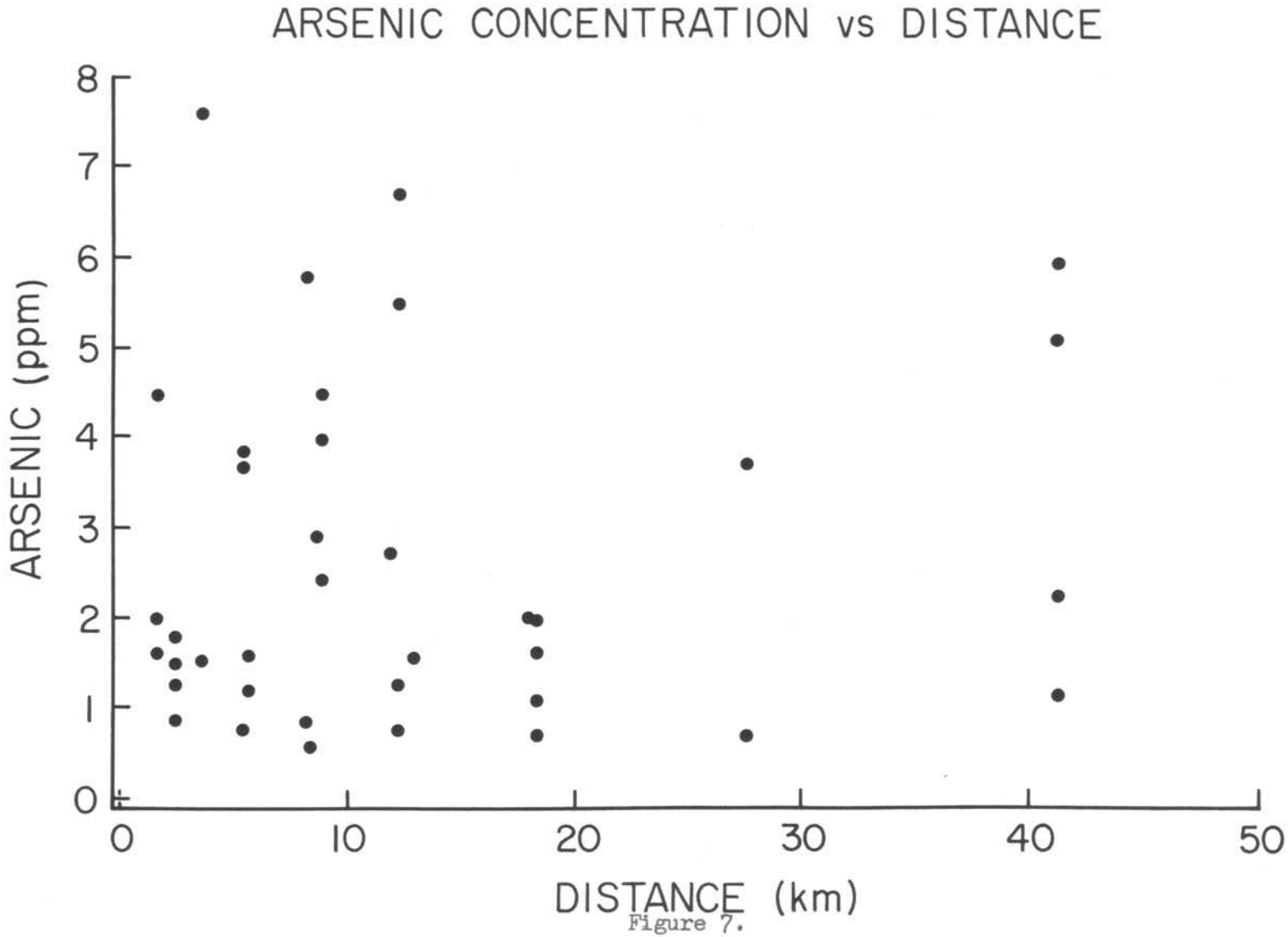
Figures 5, 6 and 7 illustrate the relationship of U, V and As, respectively, to distance away from the La Sal Mountains. In the pattern of data points it is quite obvious that no linear regression exists. Therefore the test for the hypothesis fails at this level of analysis. The next, more rigorous level of analysis is a comparison of means.

Comparison of Means

From the entire background population, the mean, standard deviation and standard error of mean were


URANIUM CONCENTRATION vs DISTANCE
URANIUM (ppm)
0
1
2
3
4
5
6
0
10
20
30
40
50
DISTANCE (km)
Figure 5.


VANADIUM CONCENTRATION vs DISTANCE
VANADIUM (ppm)
400
300
200
100
0
0
10
20
30
40
50
DISTANCE (km)
Figure 6.


ARSENIC CONCENTRATION vs DISTANCE
ARSENIC (ppm)
0
1
2
3
4
5
6
7
8
0
10
20
30
40
50
DISTANCE (km)
Figure 7.

determined. Table A3 lists these for all the elements analyzed. This sample population was then treated statistically by a comparison of means.

The elements examined for this study are listed in Table 1 along with their calculated (sample) means and published (model) means (Mason and Moore, 1982). Both means include some common elements associated with the sediments, typical elements that may be found in hydrothermal deposits and some of the rare earths. To compare the means the following procedure was formulated;

Hypothesis: H_0: $u_1 = u_0$

Alternative: H_1: means differ

Statistic: t (students)

Level of significance: $\alpha = 1\%$

Critical region: $|t| > 2.7$

Degrees of freedom: $\nu = 54$

Thus, if the calculated t value exceeds the tabulated t of 2.7 then H_0 is rejected and H_1 accepted with an error of 1% of incorrectly rejecting H_0.

Table 2 lists the calculated t values for the elements under consideration. Other elements analyzed but not listed were eliminated from further consideration, since they were determined to be unimportant to this study. The Table shows that most values are greater than 2.7; therefore, H_0 is rejected for each of these elements. Thus most of the element means (sample) differ significantly

TABLE 1

ELEMENTAL AVERAGES

ELEMENT	CALCULATED(ppm)	PUBLISHED(ppm)*
Na	1,270	3,300
Al	13,713	25,000
Ti	467	1,500
V	63	20
Mn	249	X0#
Cu	16	X.0#
Dy	0.80	7.2
U	2.27	0.45
K	8196	10,700
As	3.81	1.0
Mo	0.48	0.2
Sb	0.28	0.0X#
La	6.70	30
Sm	0.96	10
Yb	0.63	4.0
Lu	0.09	1.2
W	0.18	1.6
Sc	1.22	1.0
Cr	12.81	35
Fe	3255	9800
Co	2.07	0.3
Zn	19.9	16
Se	0.20	0.05
Zr	90.7	220
Ce	12.25	92
Eu	0.25	1.6
Tb	0.11	1.6
Hf	3.07	3.9
Ta	0.087	0.0X#
Th	1.79	1.7

* Values of average world-wide sandstones from Mason and Moore, 1982.

The X symbols are taken from Mason and Moore (1982) and represent a range of values from 1 to 9. For the purposes of this study they have been replaced with the median of 5 for use in the t-test.

TABLE 2

t-TEST VALUES

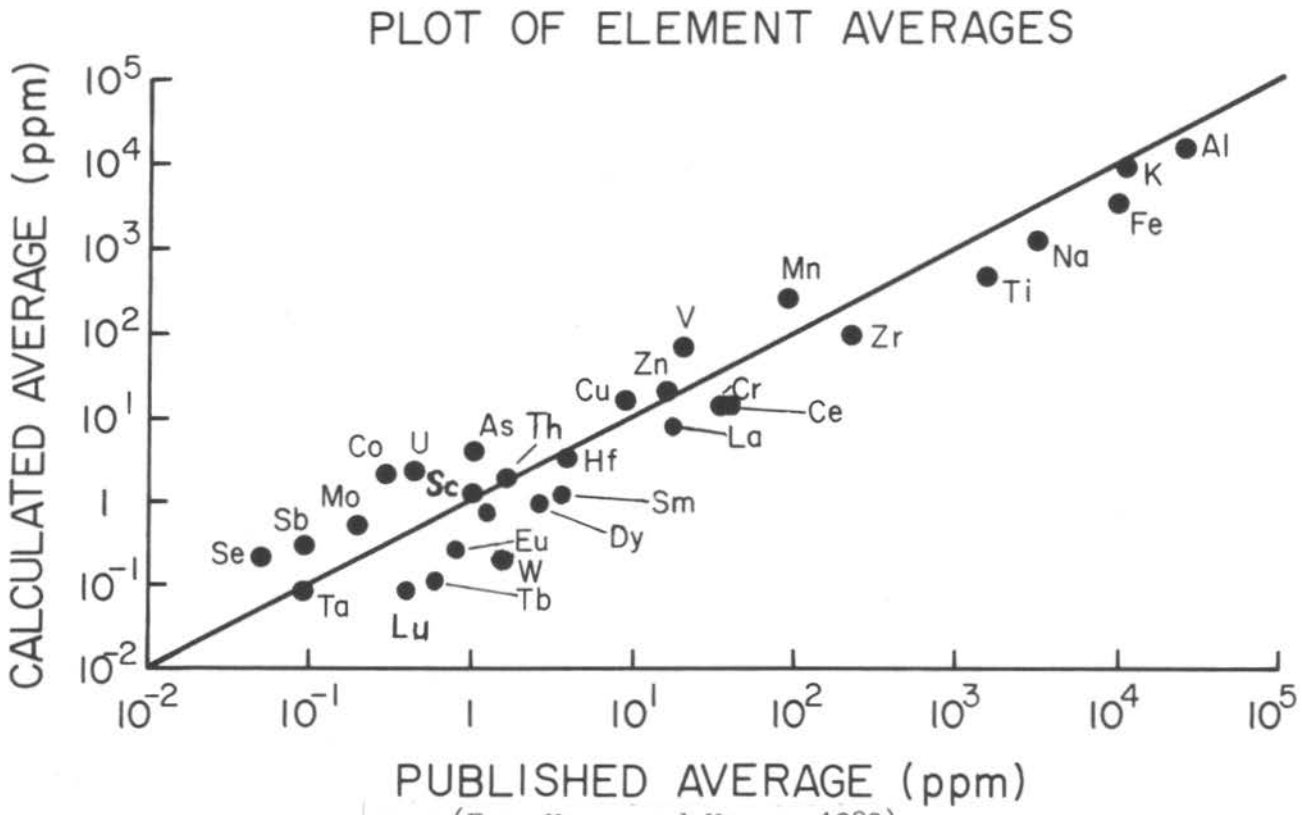
(Tabulated t=2.69, α =1%)

ELEMENT	CALCULATED t	SIGNIFICANT DIFFERENCE?
Na	7.82	Yes
Al	16.49	Yes
Ti	24.44	Yes
V	3.68	Yes
Mn	7.91	Yes
Cu	1.18	No
Dy	118.53	Yes
U	4.91	Yes
K	3.33	Yes
As	3.02	Yes
Mo	1.12	No
Sb	7.15	Yes
La	65.91	Yes
Sm	159.11	Yes
Yb	102.94	Yes
Lu	184.77	Yes
W	13.81	Yes
Sc	3.57	Yes
Cr	8.70	Yes
Fe	27.74	Yes
Co	8.94	Yes
Zn	1.81	No
Se	1.54	No
Zr	14.43	Yes
Ce	125.62	Yes
Eu	102.28	Yes
Tb	125.0	Yes
Hf	3.8	Yes
Ta	2.85	Yes
Th	1.28	No

from the model means. It seems that some particular quality or property of the sandstones is being reflected by the values. To illustrate any possible qualities, the elemental means were plotted, sample vs standard (Figure 8).

Examination of the plot provides information on relative abundances of the elements. In Figure 8, the straight line represents concentrations where elements of the sample and standard populations are equal. The area below the line encompasses those elements that show a deficiencies relative to the standard, while points above the line show excesses relative to the standard. In this study it is assumed that the model population is "ideal", that is, it represents relatively unmineralized, unaltered sandstones. On this basis, the cases showing deficiencies represent depletion and the cases illustrating excesses represent enrichment relative to average sandstones. Consulting Figure 8 it is easily seen that the Salt Wash sandstones seem depleted in the common, mineral-forming elements such as Na, Al, K, Fe and Ti. Also, they seem enriched in some common ore metals such as U, V, As, and Co.

Shoemaker and others (1959) conducted a study on the elemental composition of ore-bearing sandstones in the Salt Wash Member. In it they devised a classification system that grouped the elements into two broad classes: intrinsic



(From Mason and Moore, 1982)

Figure 8.

and extrinsic. Intrinsic elements were defined as those unrelated to the processes of uranium mineralization. This class was further subdivided into two divisions, syngenetic and epigenetic components. The former refers to detrital minerals and the latter to minerals introduced during or shortly after diagenesis by fluids. Extrinsic elements were defined as those related to processes resulting in uranium mineralization. This class also was divided into two divisions, ore and accessory components. The ore components are, namely, U and V. The accessory components are metals associated with the ore minerals. In addition to classifying, Shoemaker and others (1959) stipulated that no particular source for the extrinsic elements was implied. The elements may have easily been derived from the beds as from some external source to the sandstones.

Table 3 compares the elements of this study to those reported in Shoemaker and others (1959). The Table illustrates some elements showing enrichment (U, V, As, Co) are related to ore mineralization. However, the elements Cu, Mo, Zn, and Se related to ore mineralization have no significance ($|t|<2.7$) in this study, even though they appear to exhibit enrichment. The elements classified as intrinsic, Al, Cr, Fe, Ti,...etc. generally are depleted. The exceptions are Mn, Sb, and Sc which are enriched.

Three hypotheses are cited here to account for the variations seen in Figure 8. The first idea is that the

TABLE 3

ELEMENT COMPARISONS

ELEMENT	THIS STUDY	SHOEMAKER AND OTHERS(1959)
Na	depleted	intrinsic, syngenetic
Al	depleted	" "
Ti	"	" "
V	enriched	extrinsic, ore
Mn	enriched	intrinsic. epigenetic
Cu	no significance	extrinsic, accessory
Dy	depleted	---
U	enriched	extrinsic. ore
K	depleted	intrinsic, syngenetic
As	enriched	extrinsic, accessory
Mo	no significance	extrinsic, accessory
Sb	enriched	intrinsic, syngenetic
La	depleted	" "
Sm	"	---
Yb	"	extrinsic, accessory
Lu	"	---
W	"	---
Sc	enriched	intrinsic, syngenetic
Cr	depleted	" "
Fe	"	" "
Co	enriched	extrinsic, accessory
Zn	no significance	intrinsic, syngenetic
Se	"	extrinsic, accessory
Zr	depleted	intrinsic, syngenetic
Ce	"	---
Eu	"	---
Tb	"	---
Hf	"	---
Ta	no significance	---
Th	"	---

sample population could have sandstones less argillaceous than that of the model. Secondly, the variations could be due to effects of surface weathering, since the samples were taken from outcrops. Thirdly, the variations reflect the effect of groundwater solutions leaching the sandstones.

The first case seems entirely plausible. It is conceivable that the model population may have greater amounts of feldspar, clay and Fe-Ti minerals. This, indeed, will give the results observed with respect to the intrinsic elements. Thus the observed differences may be a function of differences in detrital composition between the sample and model populations. However, in the average sandstone model of Mason and Moore (1982) it is assumed that the samples represent an unmineralized, unaltered sandstone. Also, the data for the elemental concentrations of an average sandstone have been compiled from a number of sources by Mason and Moore (1982). Thus it is likely that an uneven distribution of the element concentrations would occur in Figure 8 if the abundances in the samples vary because of clay or detrital mineral content. This does seem to be the case. If the average sandstone model is more argillaceous than the Salt Wash Sandstones, then some of the extrinsic elements (U, V, Co, As) and Sc should be observed to fall close to or, even, below the 1:1 line in Figure 8. This would occur because these elements are

adsorbed or intimately associated with clay minerals, contained in iron hydroxides or fixed by organic matter in sediments (Goldschmidt, 1954, Granger and Waters, 1953, Krauskopf, 1979). Also, the fact that the concentrations generally lie close to the line indicates the sample population closely approximates the average model sandstone of Mason and Moore (1982). Therefore, it is reasoned that the average sandstone model does not contain greater amounts of feldspar. clay, and Fe-Ti bearing minerals.

The second hypothesis, that the variations are due to the effect of surface weathering, appears equally as valid as the first. Weathering will undoubtedly cause deficiencies in the intrinsic elements related to rock composition. However, a concomitant depletion in the extrinsic elements U, V, Co, As should also occur, since in oxidizing environments U and V have high mobilities and Co and As have moderate mobilites (Plant and Raiswell, 1983). In addition, it should be restated that relatively unweathered portions of outcrops were sampled. Thus, it is concluded that surface weathering has had little influence in the observed distributions.

The third hypothesis, that variation is due to the effect of groundwater solutions leaching the sandstones seems the most reasonable. Many workers (Adler, 1974; Gableman, 1977; Woodmansee, 1958, among others) have demonstrated the role of groundwater in the formation of

uranium deposits, especially those exhibiting the "roll" configuration. Groundwater solutions must have had some role in dissolving and transporting those components, now seen in the ore deposits, which were formerly present in the host sandstones.

Further examination of the data with respect to the rare-earth elements (REE) enhances the above discussion. Figure 9 is a comparison of REE for four "suites" of rock. The REE values are normalized against chondritic meteorite values and plotted versus atomic number. The meteorite values have been taken from Boynton (1984) and are listed in Table A5. Also, values for the North American Shale Composite (NASC) of Haskin and others (1968) are listed. The four suites of rock are: the North American Shale Composite of Haskin and others (1968) (curve 1), the average "model" sandstones of this study (curve 2), a "ratio" model (curve 3), and the Salt Wash Member sandstones (curve 4). Curve 3, the "ratio" model was calculated using the relation:

$$X = (A)^2/B$$

where: X = the curve value

A = REE:Chondrite ratio of the "model" sandstones

B = REE:Chondrite ratio of N.A. shale composite

The purpose of raising the REE:Chondrite ratio, for the average model sandstone, to the second power and dividing by the REE:Chondrite ratio for the N.A. Shale Composite is

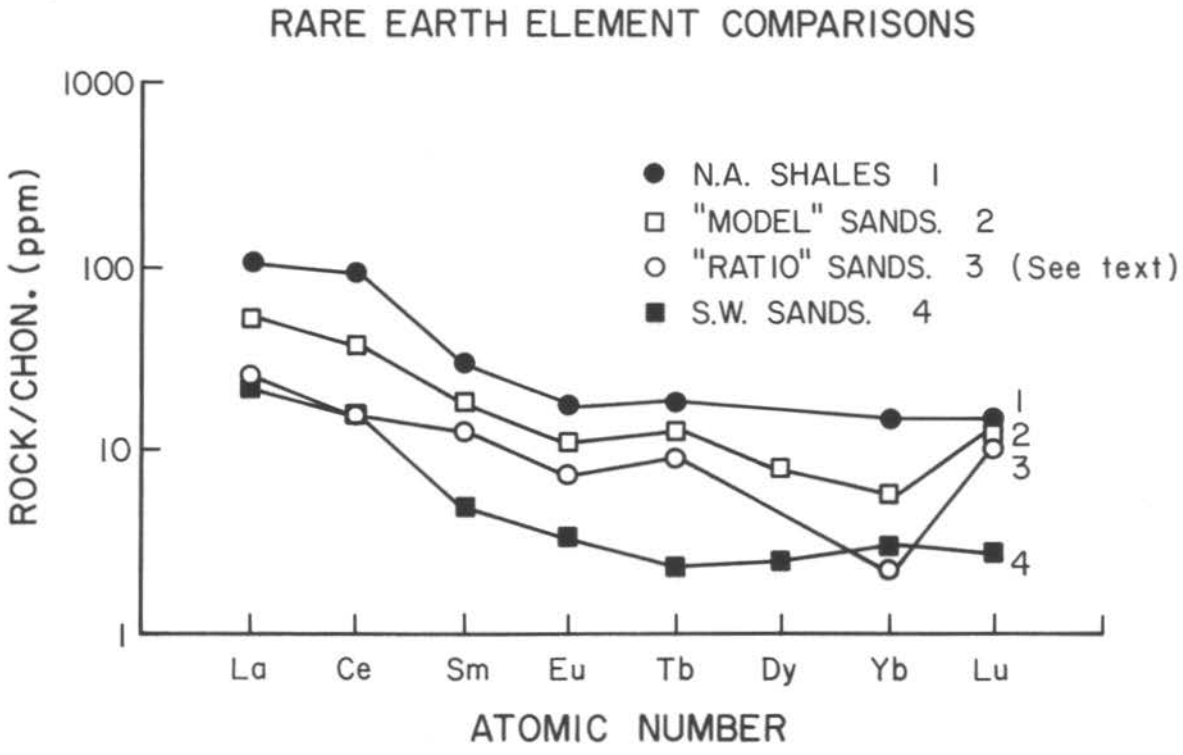

RARE EARTH ELEMENT COMPARISONS
1000
100
10
1
ROCK/CHON. (ppm)
N.A. SHALES 1
"MODEL" SANDS. 2
"RATIO" SANDS. 3 (See text)
S.W. SANDS. 4
1
2
3
4
La
Ce
Sm
Eu
Tb
Dy
Yb
Lu
ATOMIC NUMBER

Figure 9.

to get a curve that mathematically approximates a sandstone with much lower clay material than the average model sandstone. This, therefore, takes into account the possibility that the "model" sandstones may represent a sandstone containing higher amounts of clay or feldspar minerals than previously assumed.

Figure 9 illustrates that the Salt Wash sandstones seem to have a deficit, or depletion, in the REE relative to the model sandstone. Curve 1, the shale composite, shows the highest values for the REE, as expected. Typically, clays adsorb significant quantities of the rare earths. Fleet (1984) notes that as clay content decreases, progressing from shales through sandstones to limestones, so does the REE content. In accordance with this, curve 2, the "model" sandstone, displays a decreased REE content relative to curve 1. It is readily apparent that the REE concentrations of the Salt Wash sandstones, curve 4, fall below curve 3 and well below the average sandstone (curve 2) model. Generally, with the exception of La, Ce and Yb, there seems to be a deficiency of the REE in the Salt Wash sandstones. However, it must be remembered that curve 3 is a computed value which may not have true significance for the rocks considered here. For the purposes of this study it is assumed that curve 3 is deemed a reasonable model for pure sandstones. Thus, the Salt Wash Member sandstones seem to be exhibiting a depletion of REE content relative

to this assumed natural model.

It appears that the variations of elements in Figure 8 and 9 are due to groundwater interactions as the sediments have become depleted in the intrinsic elements, especially the rare earths. The next task is to determine where selected elements of the sandstones are residing, mineralogically. This is explored through the use of correlation coefficients.

Correlation Coefficient Analysis For Selected Elements

The examination of correlation coefficients focused on the rare earth elements (REE) and a few key intrinsic syngenetic components. The elements analyzed in this study are listed in Table A1. Others not listed were not analyzed by INAA (see Table A1) with the exception of Nd. Neodymium data were eliminated because it was learned that the results are in error (Sammy Garcia, Los Alamos Omega West Reactor, pers. comm.). It was decided that the rare earths should be scrutinized, as they will yield the maximum amount of information due to their "geochemical coherence" in geological environments (Goldschmidt, 1954).

Significant correlations between elements were obtained at the 1% level of significance (α). The criterion to be met for the elements to exhibit significant correlations are $r>0.348-0.372$ when $n=40-55$ and $\nu=38-53$. Table A4 lists the correlation coefficients of the elements.

Al,K,Fe,Ti,Sc and REE Correlations and Implications

The results yielded significant correlations between the elements Al, Ti, Fe, K and Hf, Th, REE (Table A4). The strongest correlations were obtained between Al, K, Th the REE and Sc. The values reflect a high degree of linear correlation in every case, except Tb. Figures A1 to A16 (Appendix I) illustrate the linear relationship between Al, K and the REE, in general. In the figures a least squares regression line is plotted to emphasize the degree of linear correlation between the elements. It is easily seen that the data for all the REE, except Tb, plotted versus Al and K show a similiar clustering of the points. Terbium exhibits a "shotgun" pattern of distribution. However, its correlation coefficients with Al and K (Table A4) are high enough for it to qualify for significance. In addition, the REE show a stronger correlation to Al than to K. This is illustrated in the close fit of the data for the REE versus Al.

The data seem to indicate a definite physical relationship of the REE to aluminum-silicate minerals in the sandstones. Specifically, clay minerals may be the sites where the REE are residing. Fleet (1984) noted that "a substantial proportion of the REE contents of clays can be held loosely on the clays and, therefore, is available to take part in exchange reactions..., although such reactions prove very difficult to quantify...".

Hydromuscovites and minerals of the illite group are possible contenders for the sites of exchange reactions in the Salt Wash sandstones. These clays have the general chemical formulae of $K_{2-x}Al_4Si_6Al_2O_{20-x}(OH)_{4+x}$ for hydromuscovite and $K_{2-x}Al_4(Si_{6+x}Al_{2-x})O_{20}(OH)_4$ for illite (Deer and others, 1966). Cation exchange reactions occur at the sites of inter-layer K ions and isomorphous substitution occurs at octahedrally coordinated Al sites.

Cadigan (1959) outlined the composition of the Salt Wash sandstones. Generally they consist of quartz, potassium and sodium feldspars, chert, tuff, metamorphic rock fragments and the clay minerals hydromica (illite), montmorillonite, and kaolinite. He noted that the dominant clay mineral is hydromica with mixed-layer clays. This is reinforced by an earlier study done by Granger and Waters (1953), focusing on the alteration of volcanic debris in sandstones associated with uranium deposits on the Colorado Plateau. In a number of Salt Wash sandstones tested for clay composition, the chief clay mineral was found to be hydromica. In yet another study, Hathaway (1959) examined vanadium-rich clays from sandstones obtained at a number of mine localities on the Colorado Plateau. X-ray analysis showed the mineralogy of the clays to consist of roscoelite (a green, vanadium hydromica) to mixed-layer mica-montmorillonites and chlorites.

Therefore given the data of figures A1 to A16, along

with the foregoing discussion, it is clear that the REE have a strong association with clay minerals, particularly hydromuscovites and illites (hydromicas), within the sandstones. However, another possibility is that the REE may be contained within feldspathic minerals.

Rankama and Sahama (1950) noted that the REE are also found in potassium feldspars, a common constituent of the Salt Wash sandstones (Cadigan, 1959). The explanation for this is that the REE substitute for K in the minerals. Indeed, this seems to be indicated in the high correlation coefficients between Al and K and the REE (Table A4). Figure A17 illustrates this relationship. The Figure shows the close correspondence between Al and K, as expected to be exhibited by potassium feldpars. A re-examination of the REE data is necessary to resolve the question of where the REE are residing: clay or feldspathic minerals?

Henderson (1984) reviewed the geochemistry of the REE. He showed that, generally, the REE exist naturally in a trivalent state. This, coupled with their large ionic radius (1.69 Å for La to 1.56 Å for Lu), makes them not easily suited for substitution into minerals. As a result the REE tend to remain associated throughout geologic environments. Hence, their "geochemical coherence" as described by Goldschimdt (1954). However, there are a few exceptions, namely Eu and Ce. Eu also exists naturally in a divalent state and Ce in a tetravalent state. The

divalent nature of Eu makes it especially suitable for substitution into minerals. The consequence is that Eu may be found concentrated in major igneous minerals, such as potassium feldspars (Goldschimdt, 1954). Given this information one may expect Eu to have a closer correspondence to Al or K than the other REE, if it were indeed concentrated in feldspars of the sandstones. This is not borne out in Figures A1 to A16. Eu demonstrates less correspondence with Al than does La, Ce, Sm, Dy, or Yb, with the exception of Tb. Further, the general similiarities of the clustering in the data for the REE suggests that the elements are, indeed, behaving as a coherent group. This implies that Eu is occurring in a trivalent state. Rankama and Sahama (1950) stated that "During the weathering, bivalent europium is largely oxidized to the trivalent state and then follows the other lanthanides being precipitated in the hydrolysates." Here they speak of weathering from limestones but this applies equally as well to feldspars. Additionally, Goldschmidt (1954) noted that during weathering and transport all the REE are "...again assembled nearly completely in the hydrolysate minerals...", such as clays, bauxite minerals and iron oxides.

A further independent method of checking the site of residence for the REE is seen in the use of Sc. Sc is a trivalent element with an ionic radius much smaller than

that of the REE (1.44 Å compared to 1.56 Å for Lu, the smallest REE). This makes it suitable for exchange reactions. Figure A18 illustrates the relationship of Sc to Al. The data show a close correspondence of the two elements. This might occur through the substitution of K by Sc at the inter-layer positions of a clay mineral. The correlation coefficient of Sc with K is significantly high enough to lend some credence to this interpretation.

Rankama and Sahama (1950) and Goldschimdt (1954) determined that Sc is entirely concentrated in the ferromagnesian minerals of igneous rocks, with little or none contained in accompanying feldspars. Further, Rankama and Sahama (1950) noted that the Sc not captured by minerals during the crystallization of a magma is concentrated in the residual fluids. Thus, ore minerals are generally enriched in this element. With respect to sedimentary rocks, Goldschimdt (1954) stated that Sc is precipitated by clay minerals and contained in metallic oxides.

These properties, in conjunction with the high correlation coefficients of Al and K with Sc and of Sc with the REE (Table A4), practically assures that the site of residence for the REE are in the clay minerals of the sandstone.

Yet another possibility where the REE may occur in the sandstones are in iron and titanium-minerals (such as

pyrite and illmenite). Table A4 lists the correlation coefficients of the REE and Sc against Fe and Ti. Generally, less prominent correlations are illustrated by these elements, but even here the correlations seem to approach the linearity illustrated by the REE with Al and K, Figures A1-A16.

It is concluded therefore that the REE are primarily associated with clay minerals, probably hydromuscovites and illites, within the sandstones. Some of the REE may be contained in feldspathic minerals. However, the general "geochemical coherence" illustrated by the REE and Sc suggests the majority of the elements are in the clays. In addition, significant quantities of the REE also occur in Fe and Ti bearing minerals. The occurrence of REE associated with these minerals implies that the REE are syngenetically or epigenetically related to the sandstones. However, Sc may be indicative of exotic groundwaters, possibly emanating from the La Sal intrusions, since Sc is concentrated in residual magmatic fluids. This interpretation is not however required by the data.

Al,Fe,Ti,Zr,Hf and Th Correlations and Implications

Zr exhibits significant correlation with Ti, and Hf (Table A4). Indeed, Hf appears to be strongly related to Zr. Rankama and Sahama (1950) and Adams and others (1959) reviewed the occurrence of Th and U and indicated that Th, Hf and Zr are usually intimately associated. This seems to

be the case here for Hf and Zr, but, Th shows a significant departure from this rule. Here, thorium has a high degree of correlation with Al, K, and Sc and a low degree with Hf and Zr (Table A4). Figures A19 to A27 (Appendix I) illustrate these correlations.

Figures A19, A20, A21, and A22 show Hf-Zr, Hf-Fe, Hf-Ti and Hf-Al correlations, respectively. It is obvious that Hf is definitely linked to Zr and Ti and but loosely linked to Fe and Al. This is evidenced by the relatively close clustering of the data points about the least squares regression line for Zr and Ti as opposed to Fe and Al. Figures A23, A24, A25, A26, and A27 show Th-Zr, Th-Fe, Th-Ti, Th-Al and Th-Hf associations. They illustrate that the association of Th with Hf is low, with Zr it is weak, with Ti and Fe it is moderate and with Al it is strong.

It seems that Hf is primarily contained in zirconium minerals. Thorium, however, seems to be associated with clay minerals primarily, either adsorbed on or incorporated into them, and secondarily to Fe-Ti minerals. This runs counter to established ideas where thorium resides chiefly in the zirconium minerals (Goldschmidt, 1954; Adams and others, 1959) and Fe-Ti minerals (Faul, 1954). However, Rankama and Sahama (1950) reported that thorium is concentrated by clays from solutions weathering thorium bearing minerals. This seems to support the site of residence for thorium in this study. It is possible that

the thorium seen here comes as a result of solutions dissolving or leaching Fe-Ti minerals, from solutions derived from the intrusions of the La Sal Mountains, or from the decomposition of uranium-bearing phases. Thus this may indicate solutions leaching the sandstones as was previously supposed. However, the pattern seen may also be the result of thorium being associated with the REE (Rankama and Sahama, 1950). Indeed, the correlation coefficients (Table A4) indicate a close relationship of Sc and the REE to Th, similar to Th-Al. Therefore, it is concluded that Th, the REE, and clay minerals form a common habit of association in the sandstones.

Since thorium also occurs with uranium in geologic environments (Rankama and Sahama, 1950), it is natural to investigate this relationship. Figure A28 illustrates that there appears to be no significant linear relationship between U and Th. Figure A29 reinforces this even further. In the Figure, uranium is plotted versus the Th/U ratio (Method from McLennan and Taylor, 1979, 1980). The exponential nature of the curve shows that there is no correlation betweeen U and Th (see also Table A4). Thus, it is unlikely that Th is directly associated with U in the sandstones.

Studies done by McLennan and Taylor (1979, 1980) and Taylor and Fryer (1982) showed that a pattern similar to Fig. A29 is characteristic of uranium deposits, where it is

inferred that deposition of uranium ore occurred from low temperature, hydrothermal solutions. It is significant that this characteristic is being displayed by the Salt Wash Member sandstones. The next step would be to make a similiar characterization of the geochemistry of the uranium ore, namely uraninite.

Discussion on the Chemical and Physical Characteristics of the Ore-Forming Solutions.

Hostetler and Garrels (1962) studied the processes of transportation, in solution, involving uranium and vanadium. They emphasized a thermodynamic mechanism for transport based on the mineralogy of the ores and illustrated it using the $U-O_2-H_2O$, $U-O_2-H_2O-CO_2$ and $U-V-K-O_2-H_2O-CO_2$ systems. From their data they formed the following interpretations:

1) CO_2 introduced into the $U-O_2-H_2O$ system increases the solubility of uraninite.
2) Oxidizing conditions favor carnotite precipitation, reducing conditions favor uraninite and montroseite formation.
3) Other ions in solution do not affect transport of U or V in the $U-V-K-O_2-H_2O-CO_2$ system.
4) Coffinite stability is similar to uraninite; roscoelite stability is similar to montroseite in the presence of excess quartz.
5) Reduction of uranium and vanadium in organic rich

and H_2S rich areas, from dilute solutions at 25°C, is sufficient to precipitate uraninite and montroseite.

Based on these deductions they concluded that transportation of uranium and vanadium occurs in a "weakly alkaline, moderately reducing ground water". Transport of U and V was by uranyl di- and tri-carbonate complexes.

Adler (1974) reviewed the formation of uranium ore deposits. He showed that uraninite in tabular deposits is associated with reducing solutions and that the "roll" ores of the Colorado Plateau may be the result of oxidizing solutions. These solutions had redistributed the uranium from the tabular deposits. To illustrate this he contrasted the Wyoming type "rolls" of the Shirley Basin and Gas Hills with the Colorado Plateau "rolls". The Wyoming type ores are known to have formed from oxidizing, slightly alkaline bi-carbonate bearing groundwaters (Granger and Warren, 1974; Dahl and Hagmaier, 1974). Therefore, it seems (as implied by Adler, 1974) the "roll" ores of Colorado and Wyoming have formed from similar solutions. Reynolds and others (1985) illustrated conclusively that redistribution of uranium by oxidizing groundwaters occurred in the Chinle Formation. The solutions deposited uranium and iron in the underlying Cutler Formation. They explained the cause of redistribution was due to uplift of the Lisbon Valley

Anticline. The solutions are characterized as oxidizing, initially having a low pH and later changing to a higher one, as redeposition proceeded. They believe this change in groundwater chemistry explains the simultaneous transport of uranium and iron.

In an attempt to obtain temperature and compositional data on the ore-forming fluids this writer tried, unsuccessfully, to locate suitable fluid inclusions in the calcite gangue of selected uraninite ore samples. However, Coleman (1957) had earlier determined approximate temperatures and pressures of formation from a number of uraninite samples taken near the La Sal Mountains area based on Fe-ZnS phase relations. He deduced a temperature of 110°C at pressures of 800 atmospheres, roughly equivalent to a depth of 3.6 Km. This is supported by recent work of Morrison and Parry (1984). They examined fluid inclusion evidence in calcite cement of the Moss Back Member, Chinle Formation, in the Lisbon Valley, at the San Rafael Swell and at Temple Mountain, Utah. The temperatures and depths of formation obtained for the three sites were, for the Lisbon Valley, 102°C and 4.3 Km, for the San Rafael Swell, 52°C and 2.3 Km, and for Temple Mountain, 70° and 3.8 Km.

It is inferred therefore, based on the literature, that a range of solutions were involved in the formation of the uranium deposits. These solutions were low temperature

and ranged from oxidizing, weakly acidic to reducing, mildly alkaline solutions. Metal ion dissolution occurred in the oxidizing solutions whereas transport and mineralization took place in reducing solutions.

Rare Earth Element Mobility

It has been shown that REE are depleted in the Salt Wash Member sandstones. Is such a "depletion" due to the effects of dissolution of the REE by groundwater solutions moving through the sandstones? To address this question it is necessary to evaluate the mobility of the REE with respect to groundwater solutions outlined in the previous section.

It has already been established in this study that the REE reside in clay minerals and, secondarily, in Fe-Ti minerals. Under what conditions are the rare earths removed from these minerals and transported in solution? Studies indicate that the REE become soluble in acidic solutions. Humphris (1984) noted that decreasing pH in groundwater solutions will favor mobilization of REE. These REE form complexes with carbonate or organic ligands. Increasing pH will cause the REE to precipitate as hydroxides or carbonates, to exchange the elements with hydronium ions at accessible mineral sites, or to become adsorbed onto mineral surfaces. Balashov and Girin (1969) illustrated acid leaching of REE from middle Jurassic clays of the Caucasus area and the Buchak Platform. They showed

that the REE reside in disseminated apatite or are adsorbed onto clays and that these became readily mobile in acidic solutions. Further, the mobilized REE exhibited a deficiency in the light rare earths (LREE=La to Eu) and an enrichment of HREE (HREE=Tb to Lu) in the acidic solution. The result was an enrichment of the LREE and a depletion of the HREE in the clays of the platform. Nesbitt (1979) studied the effect of weathering on exposed granodiorite. He showed that as the rock is weathered to clay, by solutions having a pH of 4-5, REE are released into solution. These are transported to sites of new alteration. Transport is by carbonate or hydroxyl complexes or as ions. At the new sites of weathering an increased pH, due to alteration of the feldspars to clay, results in deposition of the REE. The REE are precipitated as carbonates or hydroxides or are adsorbed onto minerals. Humphris (1984) also spoke of transport of REE by metasomatic and hydrothermal fluids. Briefly, she summarized that transport occurs under acidic conditions with complexes of carbonate, fluoride, chloride, or sulfates.

Since transport of REE can occur in heated, acidic solutions and precipitation occurs in basic solutions then it is likely that these elements have been leached from the Salt Wash Member sandstones. Warm, oxidizing, slightly acidic groundwaters must have dissolved REE from clay and

Fe-Ti minerals and redeposited them at sites where reducing conditions were prevalent. It has previously been shown that a general deficiency of the REE exists in the sandstones. If this is the case and is the result of groundwater solutions, a depletion of the HREE relative to the LREE should occur in the sandstones. McLennan and Taylor (1979, 1980) illustrate this pattern to exist in the parent rocks of uranium deposits in the Pine Creek Geosyncline of Australia. Curve 4 of Figure 9 shows that the Salt Wash sandstones also exhibit an enrichment of the LREE relative to the HREE. McLennan and Taylor (1979, 1980) further showed an enrichment of the HREE relative to the LREE existed in uranium samples from the Pine Creek Geosyncline. They suggested leaching of the parent rocks occurred with concomitant transport of the REE in low-temperature, oxidizing, alkaline hydrothermal solutions as carbonate complexes. In an analogous fashion, uranium ores from the Salt Wash Member sandstones should illustrate the same or similiar enrichment pattern of the REE to those of the Pine Creek geosyncline, if ore deposition was from low-temperature, hydrothermal solutions. This now remains to be investigated.

Rare Earth Element Geochemistry of the Ores

REE concentrations were obtained for five uraninite ore samples. Table A1 lists the samples and their locations. Three of the samples (U0, U1, U2) are tabular

ore in which the uraninite has replaced woody material, such as logs. The remaining two samples (U3, U4) were collected from roll-front deposits, where the uraninite is found interstitially in the sandstone host rock. Samples from the two types of deposits were analyzed for REE for two specific reasons. The first was to check if enrichment of the REE, in general, and specifically of the HREE has occurred in the uraninite ore relative to the host sandstones. If ore deposition has been from hydrothermal solutions, then there will be an enrichment of the HREE relative to the LREE in the ores as illustrated by McLennan and Taylor (1979, 1980) and Taylor and Fryer (1982). The second reason was to determine if any significant differences exist between the tabular and the roll-front ore. Butler and Fischer (1978) have hypothesized that the uraninite ore was deposited from meteoric solutions moving through an ancestral delta of the Salt Wash Member sandstones. This is accepted with the following modifications: 1) the tabular ore represents syngenetic mineralization; 2) the roll-ores are the result of deposition from later hydrothermal fluids; and 3) these fluids, possibly emanating from the intrusion of the La Sal Mountains plutons, leached both the sandstones and the tabular ores. Thus,the REE pattern of the tabular and roll-front ores should differ. This difference would manifest itself in an enrichment of the HREE in the

roll-front ores relative to both the sandstones and the tabular ores.

McLennan and Taylor (1979, 1980) have studied uranium deposits of the Pine Creek Geosyncline, Northern Territories, Australia. The deposits are in sandstones of the Lower Proterozoic Cahill Formation. They have shown that uraninite ore is depleted in LREE and enriched in HREE relative to the host sandstones. This pattern of REE distribution was interpreted to be the result of deposition of uranium from low-temperature, oxidizing and alkaline hydrothermal solutions which leached the host sandstones. Figure 10 is a plot of some of the data from McLennan and Taylor (1980). In the Figure, PCG 132 is a representative, unmineralized sandstone from the Cahill Formation. The remaining curves are REE data from mineralized samples. The uranium concentration for the curves are given in ppm. It is obvious from the data that there is a definite correlation between high uranium concentration and REE abundance. Further, an obvious depletion of the LREE and enrichment of the HREE in the mineralized samples relative to the host sandstone does occur.

Figure 11 is a plot of the uraninite REE:Chondrite ratios for the samples of this study. The REE have been normalized to the chondritic meteorite standard of Boynton (1984)(Table A5). It should be noted that the data for all the REE for some of the samples could not be determined.

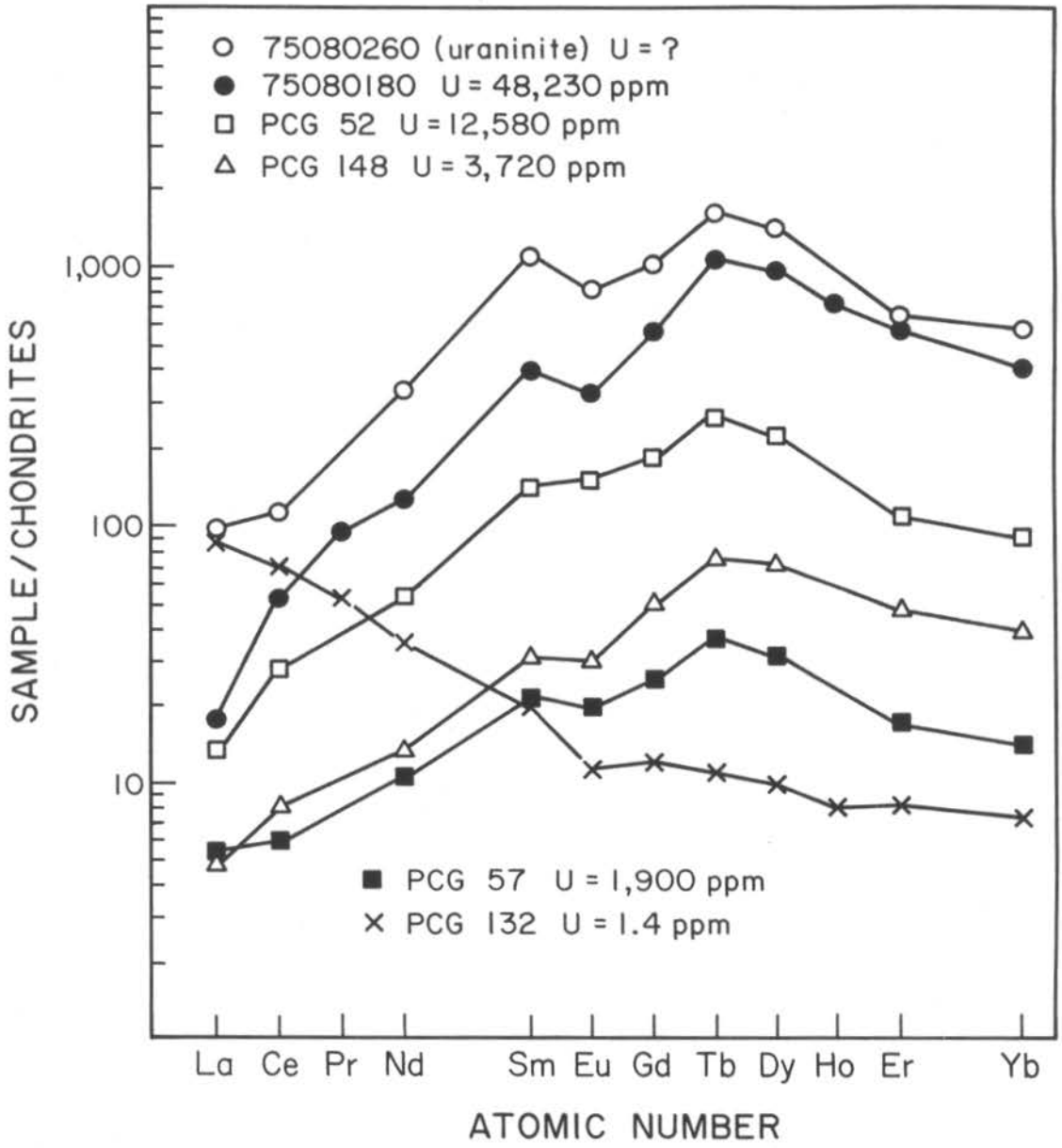

75080260 (uraninite) U = ?
75080180 U = 48,230 ppm
PCG 52 U = 12,580 ppm
PCG 148 U = 3,720 ppm
PCG 57 U = 1,900 ppm
PCG 132 U = 1.4 ppm
SAMPLE/CHONDRITES
1,000
100
10
La Ce Pr Nd Sm Eu Gd Tb Dy Ho Er Yb
ATOMIC NUMBER

Figure 10: Diagram illustrating REE patterns for uraninite samples from the Pine Creek Geosyncline, Australia. Note HREE concentrations relative to the host sandstone. Modified from McLennan and Taylor, 1980.

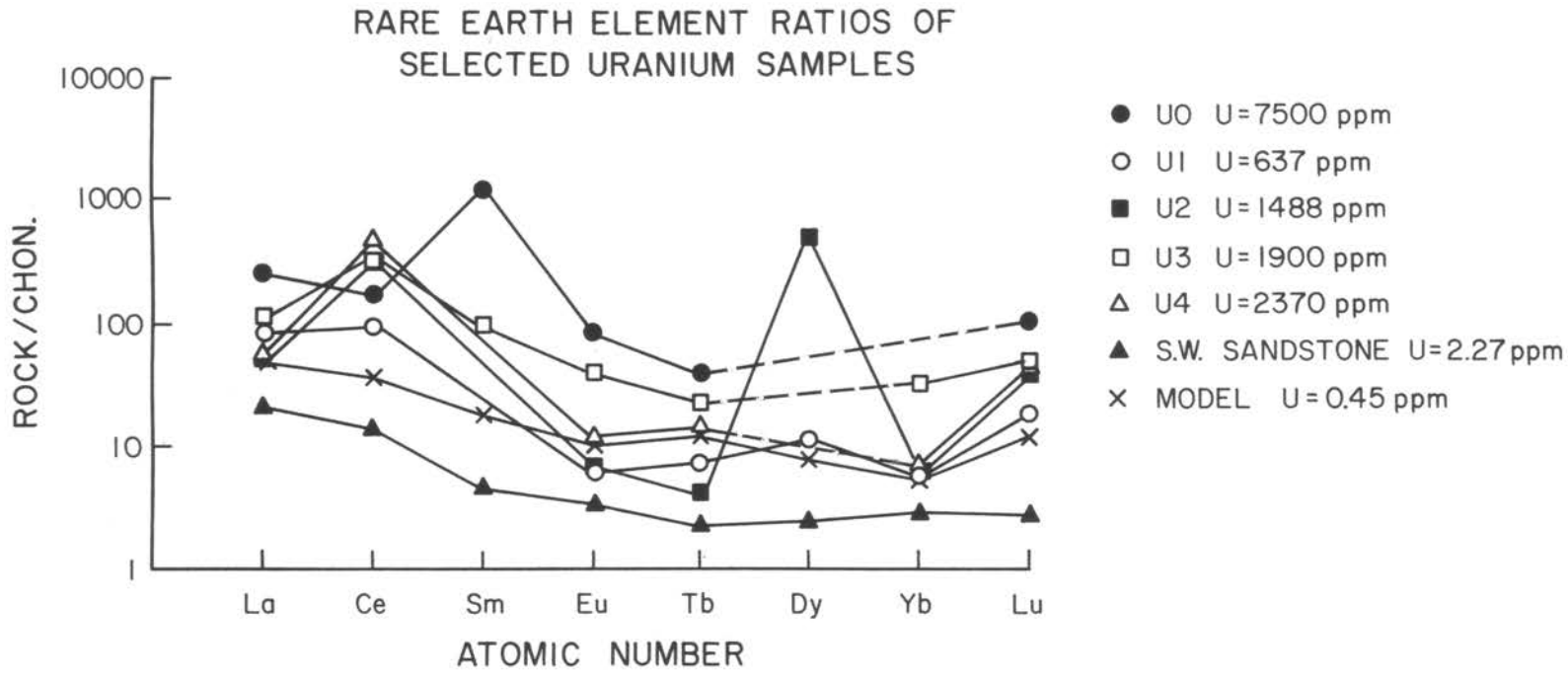


Figure 11: REE patterns for uraninite samples (U0-U4), host sandstone (triangle), and average model sandstone (cross), of this study.

High amounts of fission products were generated due to the high uranium concentration for the samples U0-U4. This caused an inability to determine the concentration of the elements affected (e.g. Dy and Yb of sample U0) from the gamma-ray spectra of INAA (Sammy Garcia, pers. comm.). The result was missing data points in a few of the curves. For comparison, the curves for the Salt Wash Member and the average sandstone "model" from Figure 9 are added.

The figure illustrates that there is a general enrichment of the REE in the uraninites, relative to both the "model" and the Salt Wash Member sandstones. However, compared to the results of McLennan and Taylor (1980), Figure 10, a pattern of depletion of the LREE and enrichment of the HREE does not exist. Rather, the REE:Chondrite ratios in general follow those of the "model" and the Salt Wash Member sandstones. Further, there appears to be no significant differences in pattern between the tabular ores (U0, U1, U2) and the roll-front ores (U3, U4). The minor anomalies in some of the curves, such as a Dy peak for U2 and Ce peak for U0, may be more an artifact of curve plotting from incomplete data. Further, the peak for Dy for the sample U2 cannot be put in its proper context, because analyses for this element for other samples were not determined.

In summary, an enrichment of REE in uraninite ore, relative to the host sandstones of the Salt Wash Member,

does occur. However, the REE patterns of the uraninite ore in the Salt Wash Member sandstones show no significant differences in enrichment of the HREE, and depletion of the LREE, relative to the host sandstones and average "model" sandstone of Mason and Moore (1982). Thus the idea that the ores were deposited from hydrothermal fluids is rejected. Also, no significant differences in the REE pattern of the tabular and the roll-front ores is observed. Rather, similarities of REE pattern in the tabular ore, roll-front ore and sandstones imply the three are syngenetically related. Therefore, the idea that redistribution of uranium from hydrothermal groundwaters, possibly emanating from intrusion of the La Sal Plutons is not supported by the data.

SUMMARY AND CONCLUSIONS

The hypothesis that hydrothermal fluids, emanating from the intrusion of the La Sal Mountains, led to a redistribution of uranium in sandstones of the Salt Wash Member of the Morrison Formation has been tested according to following criteria:

(a) Selected trace-element concentrations in the sandstones should show a spatial relation to the plutons.

(b) The sandstones should exhibit a general enrichment of common ore elements associated with U deposits such as Fe, Zn, W, U, V, Se, Sc, As, Co, and Mo.

(c) The sandstones should have a general depletion of the REE, resulting from leaching of these elements by hydrothermal fluids.

(d) The uranium-vanadium ores show a general depletion of the LREE and enrichment of the HREE, relative to the host sandstones and the average sandstone model.

Tested against these criteria this study has yielded the following results:

1) Plots of U, V, and As concentration versus distance from the La Sal Mountains exhibit no specific trend, i.e. they have no specific spatial relation to the La Sal Mountains. This finding does not satisfy criterion (a) above.

2) Although there appears to be a general enrichment of some elements generally associated with hydrothermal ore

deposits, there is a deficiency of others. The elements enriched are U, V, As, Co, and Sc, however there is a deficiency of the elements Cr, Fe, Ta, Ti, and W. This observation is inconclusive with respect to criterion (b).

3) A deficiency of rare-earth elements occur in the sandstones relative to an average model sandstone of Mason and Moore (1982). Correlation coefficient analysis of the REE and Sc with Al, K, Fe, and Ti shows the REE and Sc to be primarily associated with clay minerals, probably hydromuscovites, and secondarily to Fe-Ti bearing phases. It is interpreted from this and observation 2 that leaching of the Salt Wash Member sandstones may have occurred. Further it is inferred, based on the literature, that heated, acidic, oxidizing, groundwaters were most likely to have been responsible for such leaching. Such solutions could also have redistributed the components of the uranium deposits. Thus criterion (c) may be satisfied. U, Th, Hf, and the REE were further examined to test this case.

4) It was shown that U, Th, and Hf have no correlation among each other. It appears that Th is largely present in the clay fractions of the sandstones. Hf occurs primarily within zirconium-bearing phases. Further, there is an exponential relationship between U concentration and Th/U in the sandstones. These observations seem to support the contention that hydrothermal fluids were present to transport the REE. McLennan and Taylor (1979, 1980) found

this relation to be characteristic of sandstones hosting hydrothermally deposited uranium ore in the Pine Creek Geosyncline, Northern Territories, Australia.

5) REE concentration of uraninite ore exhibits an enrichment relative to the Salt Wash Member sandstones. However, there is no enrichment of the HREE, and depletion in the LREE, in the ore relative to the host sandstones and an average sandstone model of Mason and Moore (1982). Further, there are no significant differences in the REE pattern of the tabular ore and the roll-front ore. Rather, the patterns of the tabular, roll-front ore, and host sandstones are similiar. These observations do not satisfy the conditions specified in criterion (d). The work of McLennan and Taylor (1979, 1980) illustrates that this condition is absolutely necessary if ore deposition was from hydrothermal fluids.

In conclusion, the hypothesis that the intrusion of the La Sal Mountains plutons was in some way responsible for a redistribution of uranium in the Salt Wash Member sandstones must be rejected. Although observations 3 and 4 appear to favor the hypothesis that hydrothermal solutions leached the sandstones, observation 2 is inconclusive and observation 5 refutes the hypothesis. Similarly observation 1 suggests the La Sal Mountains intrusions were not involved. The expected linear regression patterns of the spatial test and of the LREE and HREE patterns of the

uraninite ore, indicative of deposition from hydrothermal solutions, did not occur. The similarities of the REE patterns between the ores and the host sandstones implies a syngenetic relationship. This appears to support an hypothesis by Butler and Fischer (1978) that ore deposition was from meteoric waters moving through an ancestral Salt Wash delta.

PERSPECTIVE

There is much conflicting evidence presented in the extensive literature on the uranium deposits of the La Sal Mountains region, and in the Colorado Plateau in general. Although much work has been done on models of formation, much work remains to be done. It appears that studies into the nature of these deposits should continue, although there is less incentive to do so as economic interest in the deposits has waned.

This study has been one such attempt, albeit limited in scope, to narrow the choices of models of the genesis on the deposits. The results are by no means comprehensive or fully conclusive. The initial field sampling program of this study was hindered by lack of suitable exposures. This resulted in falling short of the original design of the collection protocol. However, it is hoped that the necessary modifications have not introduced further, additional bias.

During this study the writer revised his ideas on the formation of these particular deposits. If the intrusion of the La Sal Mountains had any influence on these deposits, this influence is now believed to be minor and not major as originally supposed. The tabular ore appears to be syngenetically related to the Salt Wash Member sandstones. Deposition was, most likely, from uranium-rich meteoric solutions percolating through an ancient delta in

the Jurassic period. The uranium in solution slowly replaced decomposing woody material (in fallen tree stumps) at that time. The roll-front ores, on the other hand, appear to have had a different history. These ores were probably deposited by meteoric solutions, recirculated during uplift in the area. This uplift may have been caused by the renewed rise of salt diapirs common to the area. This would account for many of the roll-front deposits concentrated along the flanks of the salt valleys (e.g. the Paradox Valley deposits). The La Sal Mountains intrusions may also have been an additional, minor contributor to general uplift in the area.

Further work that could be done to refine these ideas would be to conduct a more detailed field sampling program involving both the sandstones and the ores. The resulting samples should then be analyzed by INAA and the geochemical data examined. Attention should be focused upon the entire suite of the rare-earth elements, not just a partial sampling of them, as was done in this study. This should result in more definitive information on the ores.

Another suggestion is to conduct further fluid inclusion studies on the calcite gangue of the uraninite ore. This study failed to get temperature and compositional data, as the samples studied were lacking in suitable inclusions. However with better samples this may still be accomplished.

Yet another avenue to study the hydrothermal activity associated with the La Sal Mountains intrusions would be to analyze the oxygen isotope composition of the Salt Wash Member sandstones surrounding the mountains. If the intrusions did set up hydrothermal circulation cells in the surrounding rocks, then this will surely be evident in the decreasing ^{18}O values with distance away from the plutons. For example, Faure (1977, pg. 365) illustrates this pattern around a Tertiary granite stock intruding volcanic country rock in the Cascade Range of Oregon. It is likely that distinctive patterns of isotope ratios would also occur in sedimentary country rock surrounding the La Sal Mountains.

Reynolds and others (1985) conducted a novel study of Cutler Formation uranium deposits in the Lisbon Valley Anticline, near the La Sal Mountains. In it they examined paleomagnetic and petrologic evidence of mineralized and unmineralized sandstones. Specifically, they focused on the natural remanent magnetism (NRM) of the rocks and the texture and composition of iron oxide coating detrital grains. Their results effectively constrained a time of formation for the deposits as Late Cretaceous to Early Tertiary, relating to uplift of the Lisbon Valley Anticline. This is also believed to be the time of formation for the La Sal Mountains. The techniques used in their study could also be applied to the Salt Wash Member

sandstones.

In a very recent study conducted by Turner-Peterson (1985) on uranium deposits in the Grants Mineral Region, San Juan Basin, New Mexico, mineralogic data from sandstones of the Morrison Formation were examined. The major evidence considered was magnetite-ilmenite grain destruction, distribution of feldspar alteration and rare-earth element distribution. She concluded that two generations of ore occurred in the sandstones: primary, tabular ore and redistributed, roll-front ore. The primary ore was formed as a result of mineral-rich fluids being expelled from mudstone and claystone lenses, during compaction of the basin, and moving into interbedded sandstone layers. The roll-front ores were deposited as a result of later basinward flow of oxygenated groundwater. In an analogous fashion, it should be advantageous to examine the same mineralogic relations in the Salt Wash Member sandstones as Turner-Peterson (1985) did for sandstones of the San Juan Basin.

Although future theories and as yet to be discovered evidence will further constrain the genesis of the La Sal Mountains area uranium deposits, controversy over their formation will probably remain, for this is the nature of geology.

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APPENDICES

APPENDIX I: TABLES

TABLE A1

LIST OF SAMPLE STATIONS (SANDSTONES)

STATION	SAMPLES*	DISTANCE(Km)
1	6200880, 6201070	1.6
2	6200480, 6200720	1.6
3	6200490, 6200670	1.6
4	6200650, 6201270	1.6
5	6200980, 6201230	2.4
6	6200550, 6201280	2.4
7	6200630, 6201210	2.4
8	6200390, 6201260	2.4
9	6200800, 6200840	3.6
10	6200590, 6200750	3.6
11	6200530, 6200960	5.5
12	6200790, 6201010	5.5
13	6200500, 6201040	5.5
14	6200400, 6201120	5.5
15	6201310, 6201330	5.5
16	6200710, 6200970	6.4
17	6200370, 6200780	8.1
18	6201140, 6201340	8.2
19	6200610, 6200910	8.4
20	6200470, 6201030	8.7
21	6201460, 6201550	8.8
22	6201570, 6201620	8.8
23	6200460, 6201020	8.8
24	6200430, 6200450	9.7
25	6200950, 6201300	10.0
26	6201320, 6201540	10.5
27	6200770, 6201160	10.5
28	6201680, 6201520	11.3
29	6201380, 6201600	11.3
30	6201360, 6201410	11.4
31	6201110, 6201180	11.9
32	6200410, 6201100	12.2
33	6200850, 6200990	12.2
34	6200740, 6200760	12.2
35	6201530, 6201650	12.2
36	6200420, 6200900	12.9
37	6200570, 6201200	18.0
38	6200730, 6201000	18.4
39	6201050, 6201290	18.4
40	6200820, 6201350	18.4
41	6201370, 6201690	18.0
42	6200620, 6201630	18.4
43	6201430, 6201440	18.4
44	6201470, 6201670	27.2

TABLE A1 (CONTINUED)

LIST OF SAMPLE STATIONS
(SANDSTONES)

STATION	SAMPLE*	DISTANCE(Km)
45	6201500, 6201590	27.5
46	6201450, 6201610	28.2
47	6200870, 6201220	28.3
48	6200560, 6200600	27.5
49	6200360, 6200860	35.4
50	6200690, 6201130	41.2
51	6200640, 6200960	41.2
52	6200510, 6201080	41.2
53	6200440, 6201510	41.2
54	6201480, 6201640	41.2
55	6200380, 6201190	57.9
56	SW-1, SW-2	0.0#
57	SW-3, SW-4	0.5
58	SW-5, SW-6	0.0#
59	SW-7, SW-8	0.5

* Sample numbers coincide with Los Alamos numbers. Samples SW-X represent sandstones taken closer than 1.6 Km.
# Samples at 0.0 distance taken close to La Sal Plutons.

Uraninite Samples

U0	Unnamed mine near Lisbon Valley (tabular ore)
U1	Firefly Mine (tabular ore)
U2	Grey Daun Mine (tabular ore)
U3	Elva Mine (roll ore)
U4	Unnamed mine near La Sal Junction (roll ore)

TABLE A2

ELEMENTS MEASURED BY INAA (THIS STUDY)

Ag - Silver
Al - Aluminum
As - Arsenic
Au - Gold
Ba - Barium
Br - Bromine
Ca - Calcium
Ce - Cerium
Cl - Chlorine
Co - Cobalt
Cr - Chromium
Cs - Cesium
Cu - Copper
Dy - Dysprosium
Eu - Europium
Fe - Iron
Ga - Gallium
Hg - Mercury
Hf - Hafnium
I - Iodine
In - Indium
K - Potassium
La - Lanthanum
Lu - Lutetium
Mg - Magnesium
Mn - Manganese
Mo - Molybdenum
Na - Sodium
Nd - Neodymium
Rb - Rubidium
Sb - Antimony
Sc - Scandium
Se - Selenium
Sm - Samarium
Sr - Strontium
Ta - Tantalum
Tb - Terbium
Th - Thorium
Ti - Titanium
U - Uranium
V - Vanadium
W - Tungsten

TABLE A3
STATISTICS

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	STD ERROR OF MEAN
NA	55	1269.2697273	1925.7014258	34.8600005	11140.000000	259.6615273
MG	55	3205.9990912	3571.8602292	0.0000010	16535.000000	481.6296160
AL	55	13713.0454545	5075.9378218	4052.5000000	28655.000000	684.4393163
CL	55	105.4329095	199.9032342	0.0000010	979.700000	26.9549496
CA	55	21044.3272729	20625.5833315	0.0000010	95230.000000	2781.1530891
TI	55	466.5681621	313.4449518	0.0000010	1219.000000	42.2649087
V	55	82.8941637	86.6207801	0.0000010	395.800000	11.6799436
MN	55	248.7033273	177.3056844	7.4000000	808.150000	23.9079206
CU	55	16.2554555	70.6131325	0.0000010	445.750000	9.5214728
SR	55	6.5088191	23.8336374	0.0000010	121.650001	3.2137270
IN	55	0.0029819	0.0221069	0.0000010	0.163951	0.0029809
I	55	0.0000010	0.0000000	0.0000010	0.000001	0.0000000
BA	55	602.9054547	1031.1891895	0.0000010	6592.500000	139.0455220
DY	55	0.7972792	0.4006227	0.1243005	2.230000	0.0540199
U	55	2.2737545	2.7570492	0.2915000	12.776000	0.3717604
K	55	8195.7645455	5579.7248689	0.0000010	25200.000000	752.3699478
GA	55	0.1638282	0.5978057	0.0000010	2.583501	0.0806081
AS	55	3.8100055	6.8698023	0.0000010	46.060000	0.9290202
BR	55	0.4025725	1.0041309	0.0000010	7.158000	0.1353978
MO	55	0.4324754	1.8566003	0.0000010	13.283000	0.2503709
SB	55	0.2803147	0.2388598	0.0000010	1.513000	0.0322079
LA	55	0.5979364	2.6218686	0.9050000	19.700000	0.3535327
SM	55	0.9594700	0.4213542	0.2240000	2.750000	0.0568154
YB	55	0.6208037	0.2427939	0.0000010	1.725000	0.0327383
LU	55	0.0382171	0.0445536	0.0000010	0.243000	0.0060076
W	55	0.1805545	0.7628772	0.0000010	5.421000	0.1026663
AU	55	0.0155591	0.0236761	0.0000010	0.110500	0.0031925
SC	55	1.2246055	0.4572431	0.2480000	2.317000	0.0616545
CR	55	12.8095818	19.9057027	2.7250000	145.770000	2.5492444
FE	55	3255.3872727	1749.5865815	616.0500000	11457.500000	235.9142065
CO	55	2.0674245	1.4682004	0.2176000	8.453500	0.1979721
ZN	55	19.9101369	16.0028606	0.0000010	91.700000	2.1578253
SE	55	0.2018232	0.7228203	0.0000010	3.565000	0.0974651
RB	55	23.9825365	15.6676979	0.0000010	61.000000	2.1126320
ZR	55	90.7151821	66.4663601	0.0000010	255.000000	8.9623222
AG	55	0.2977038	1.5613727	0.0000010	10.609500	0.2105354
CS	55	0.7819082	0.3964767	0.0000010	1.912000	0.0534609
BA131	55	611.3365456	1094.5305105	0.0000010	6933.500000	147.5864639
CE	55	12.2471637	4.7082271	0.0000010	29.250000	0.6348572
ND	55	1.0816373	3.5655868	0.0000010	17.400000	0.4807839
EU	55	0.2552726	0.0978920	0.0375005	0.565000	0.0131997
TB	55	0.1115790	0.0884470	0.0000010	0.313450	0.0119262
HF	55	3.0742164	1.6213692	0.9496500	7.485000	0.2186254
TA	55	0.0863261	0.0964169	0.0000010	0.310000	0.0130011
HG	55	0.0000010	0.0000000	0.0000010	0.000001	0.0000000
TH	55	1.7831616	0.5179065	0.5750000	3.132500	0.0698345

-Concentrations in ppm.-

TABLE A4

CORRELATION COEFFICIENTS FOR SELECTED ELEMENTS OF THE SALT WASH MEMBER SANDSTONES

	Na	Al	Ti	U	K	Fe	Zr	Th	Sc
Na	1.00	0.273	0.279	-0.009	0.146	0.169	0.040	0.338	0.259
	55	55	48	55	53	55	47	55	55
Al	0.273	1.00	0.500	0.200	0.839	0.307	0.284	0.830	0.820
	55	55	48	55	53	55	47	55	55
Ti	0.279	0.500	1.00	0.277	0.396	0.311	0.639	0.599	0.592
	48	48	48	48	47	48	42	48	48
V	-0.055	0.038	0.186	0.497	0.039	-0.206	-0.018	0.080	0.048
	54	54	48	55	53	55	47	54	54
Mn	0.042	-0.203	0.143	0.079	-0.124	0.225	0.037	-0.120	-0.006
	55	55	48	55	53	55	47	55	55
Cu	-0.246	-0.307	-0.558	0.821	-0.098	-0.317	-0.949	-0.343	-0.487
	4	4	4	4	4	4	3	4	4
Dy	0.500	0.394	0.493	0.052	0.468	0.516	0.280	0.568	0.599
	55	55	48	55	53	55	47	55	55
U	-0.009	0.200	0.277	1.00	0.165	0.001	-0.148	0.192	0.190
	55	55	48	55	53	53	46	55	55
K	0.146	0.838	0.396	0.165	1.00	0.287	0.142	0.605	0.633
	53	53	47	53	53	53	46	53	53
As	-0.068	-0.091	-0.169	0.436	-0.011	-0.187	-0.175	-0.114	-0.150
	54	54	47	54	52	54	46	54	54
Mo	0.003	-0.006	-0.155	0.532	-0.040	-0.131	-0.127	0.048	-0.036
	11	11	9	11	11	11	11	11	11
Sb	0.195	0.267	-0.085	-0.107	0.385	-0.001	-0.102	0.029	-0.063
	53	53	47	53	51	53	46	53	53
La	0.302	0.446	0.301	0.218	0.401	0.545	0.117	0.672	0.738
	55	55	48	55	53	55	47	55	55
Sm	0.288	0.497	0.359	0.176	0.490	0.595	0.161	0.657	0.745
	55	55	48	55	53	55	47	55	55
Yb	0.400	0.471	0.571	0.121	0.577	0.530	0.380	0.648	0.675
	54	54	47	54	52	54	46	54	54
Lu	0.366	0.555	0.637	0.450	0.457	0.476	0.502	0.716	0.700
	52	52	46	52	50	52	44	52	52
W	0.031	0.589	-0.260	-0.338	0.757	-0.021	-0.288	0.174	-0.115
	8	8	8	8	8	8	9	8	53
Sc	0.259	0.820	0.592	0.190	0.633	0.524	0.293	0.893	1.00
	55	55	48	55	53	55	47	55	55
Cr	-0.026	0.013	0.237	-0.014	-0.077	-0.026	0.394	0.105	0.040
	55	55	48	55	53	55	47	55	55
Fe	0.169	0.307	0.311	0.001	0.287	1.00	0.181	0.407	0.524
	55	55	48	55	53	55	47	55	55
Co	0.163	0.155	0.085	0.458	0.081	0.030	-0.079	0.263	0.244
	55	55	48	55	53	55	47	55	55
Zn	0.143	0.211	0.309	0.167	0.114	-0.089	0.009	0.302	0.189
	51	51	44	51	49	51	44	51	51
Se	-0.011	0.287	-0.162	0.149	0.584	0.636	-0.561	0.229	0.171
	6	6	6	6	6	6	6	6	6
Zr	0.040	0.284	0.639	-0.148	0.142	0.181	1.00	0.323	0.293
	47	47	42	47	46	47	47	47	47
Ce	0.308	0.548	0.391	0.249	0.435	0.550	0.157	0.721	0.800
	54	54	47	54	52	54	46	54	54
Eu	0.298	0.567	0.413	0.175	0.565	0.606	0.179	0.677	0.752
	55	55	48	55	53	55	47	55	55
Tb	0.091	0.460	0.272	0.241	0.499	0.279	0.191	0.528	0.610
	44	44	38	44	42	44	37	44	44
Hf	-0.103	0.411	0.762	0.049	0.380	0.144	0.830	0.368	0.359
	55	55	48	55	53	55	47	55	55
Ta	-0.067	0.578	0.180	0.127	0.492	-0.037	0.108	0.497	0.481
	30	30	28	30	28	30	27	30	30
Th	0.338	0.830	0.599	0.192	0.605	0.407	0.323	1.00	0.893
	55	55	48	55	53	55	47	55	55

2 digit number specifies number of stations for which the correlation coefficient was calculated (those stations that had detectable concentrations).

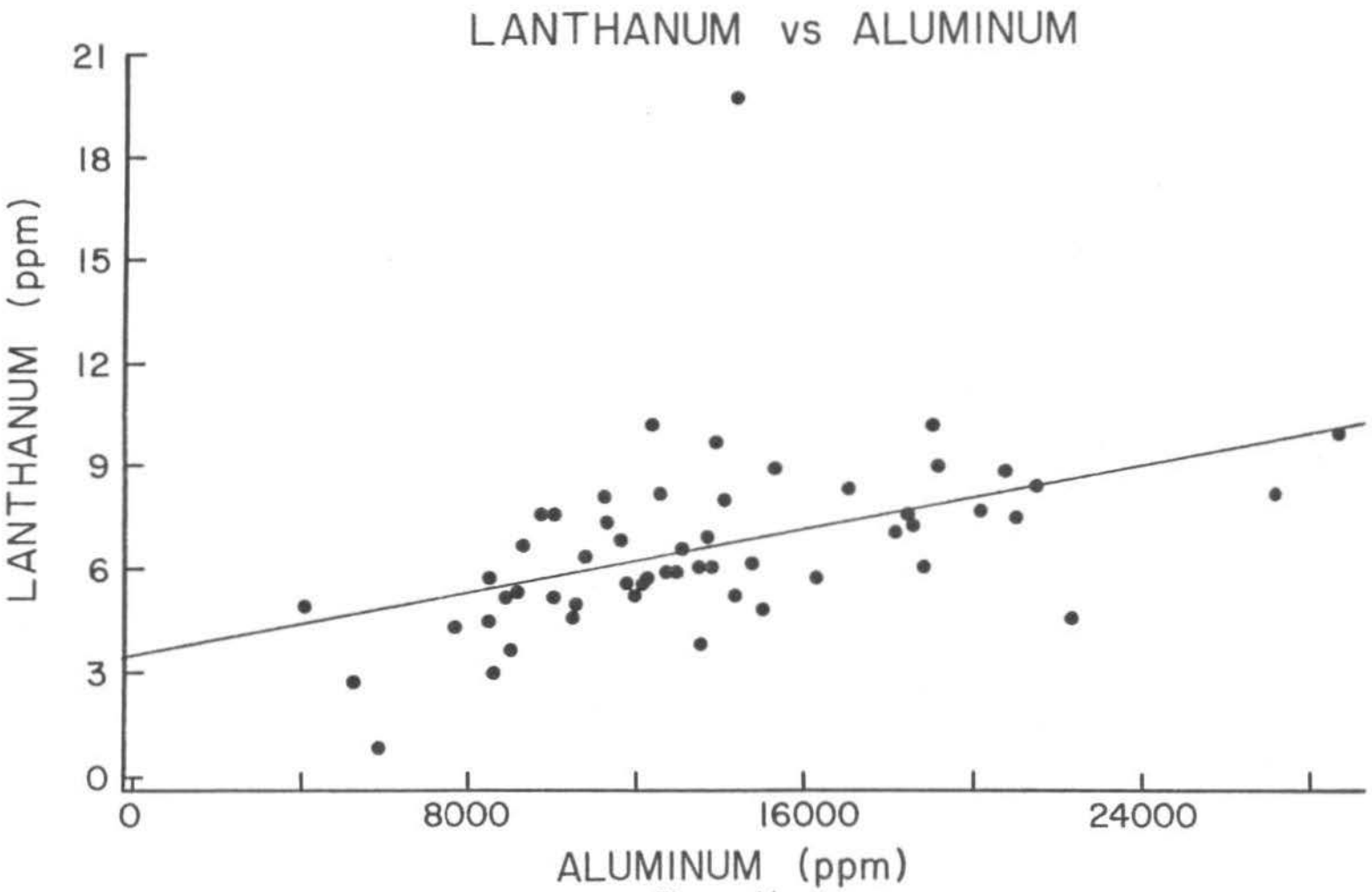
TABLE A5

RARE EARTH ELEMENT CONCENTRATIONS

ELEMENT	NORTH AMERICAN SHALE COMPOSITE*	CHONDRITIC METEORITES**
La	32	0.31
Ce	73	0.808
Sm	5.7	0.195
Eu	1.24	0.0735
Tb	0.85	0.0474
Dy	---	0.322
Yb	3.1	0.209
Lu	0.48	0.0322

* Data from Haskin and others (1968).
** Data from Boynton (1984).

APPENDIX II: GRAPHS


LANTHANUM vs ALUMINUM
LANTHANUM (ppm)
21
18
15
12
9
6
3
0
0
8000
16000
24000
ALUMINUM (ppm)
Figure A1

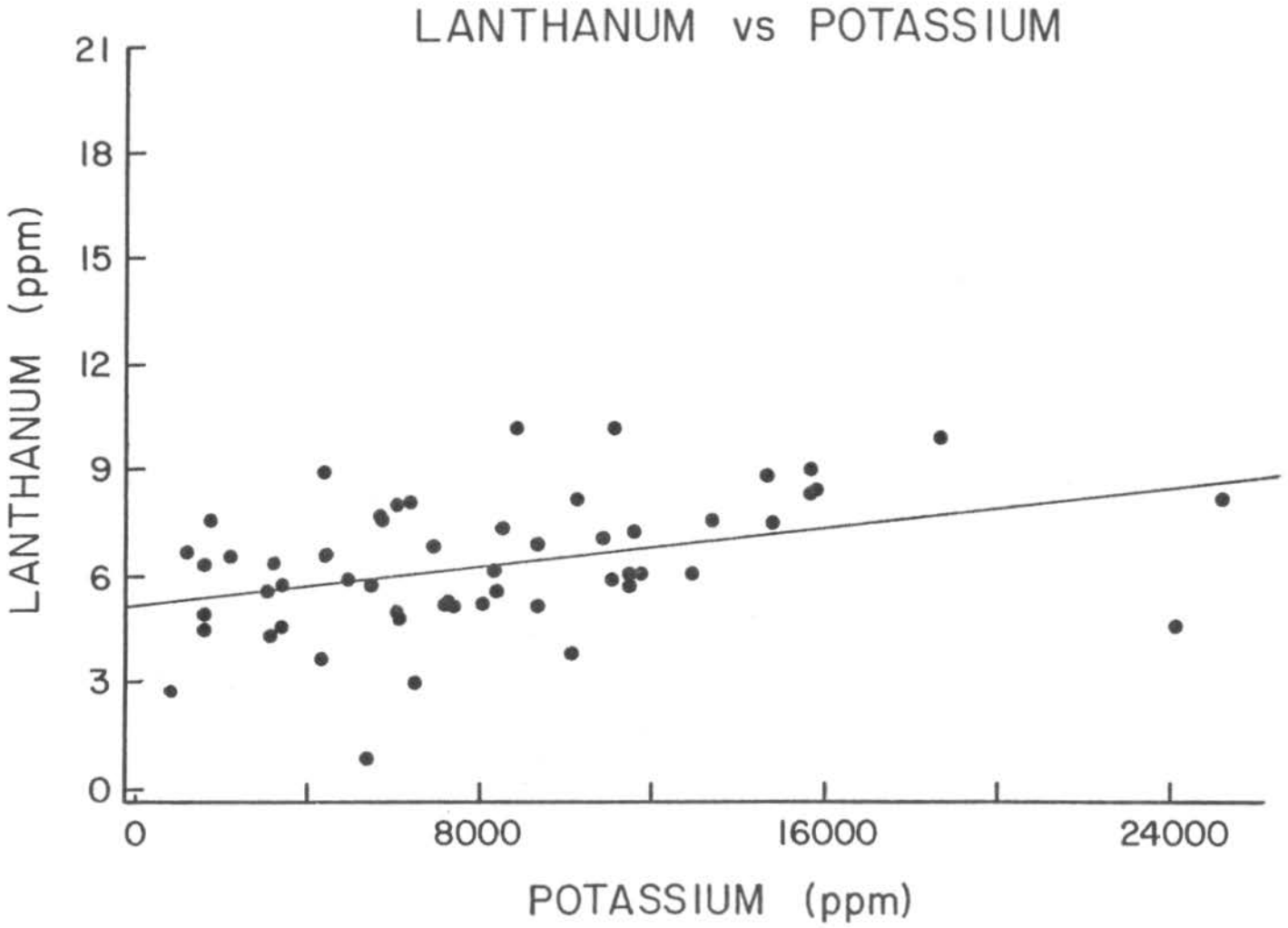
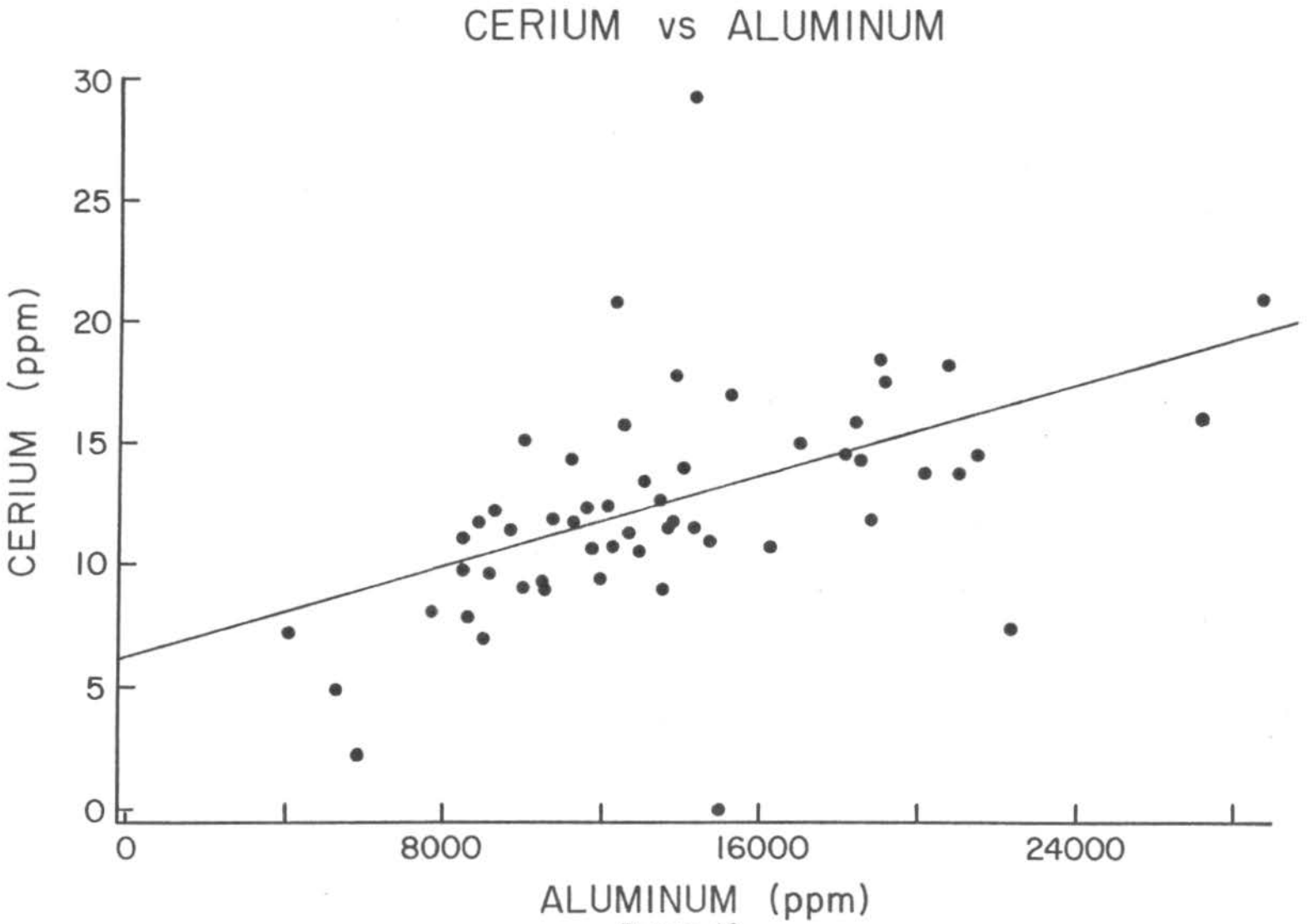

LANTHANUM vs POTASSIUM
LANTHANUM (ppm)
21
18
15
12
9
6
3
0
0
8000
16000
24000
POTASSIUM (ppm)

Figure A2


CERIUM vs ALUMINUM
CERIUM (ppm)
30
25
20
15
10
5
0
0
8000
16000
24000
ALUMINUM (ppm)
Figure A3

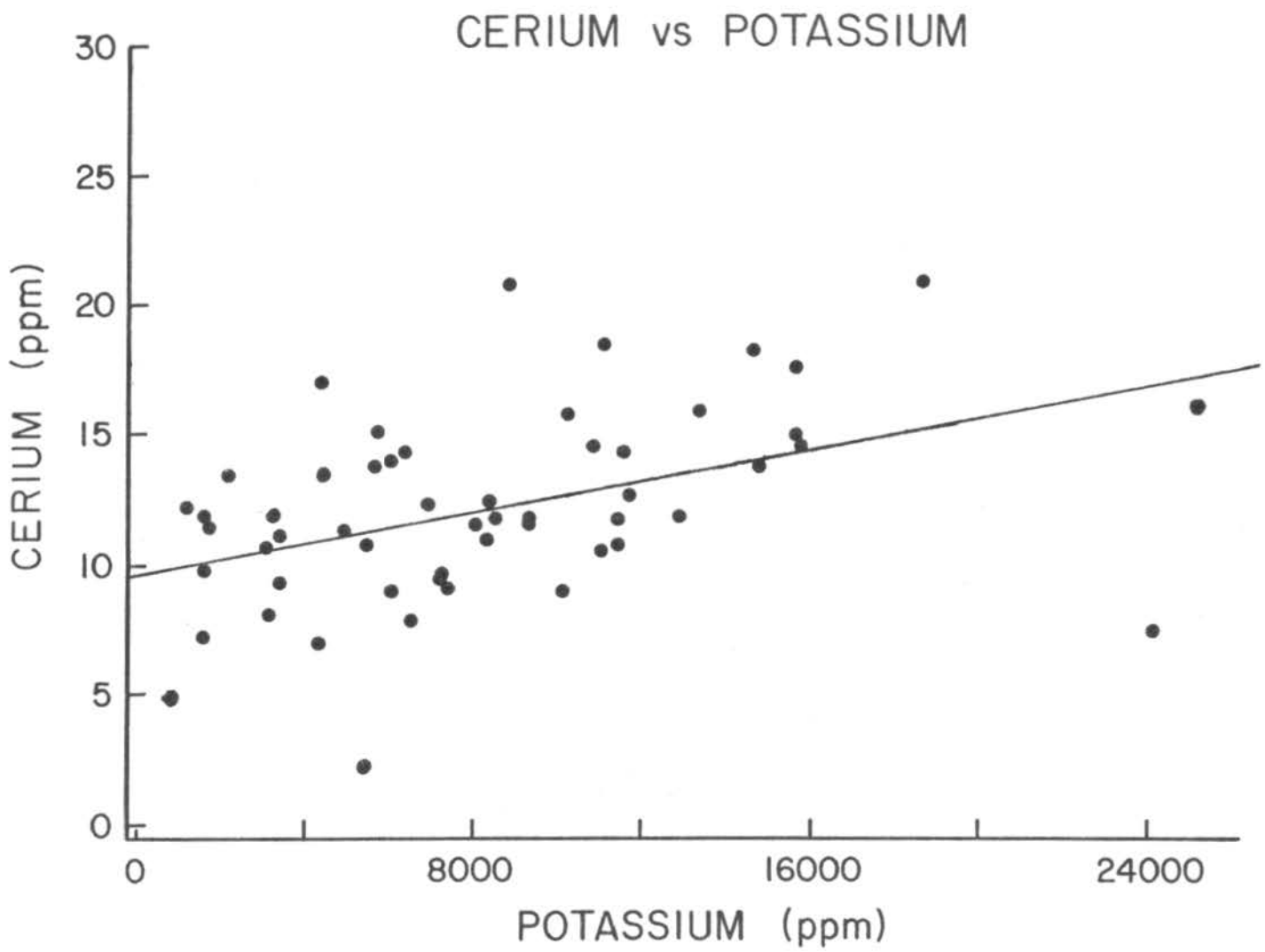
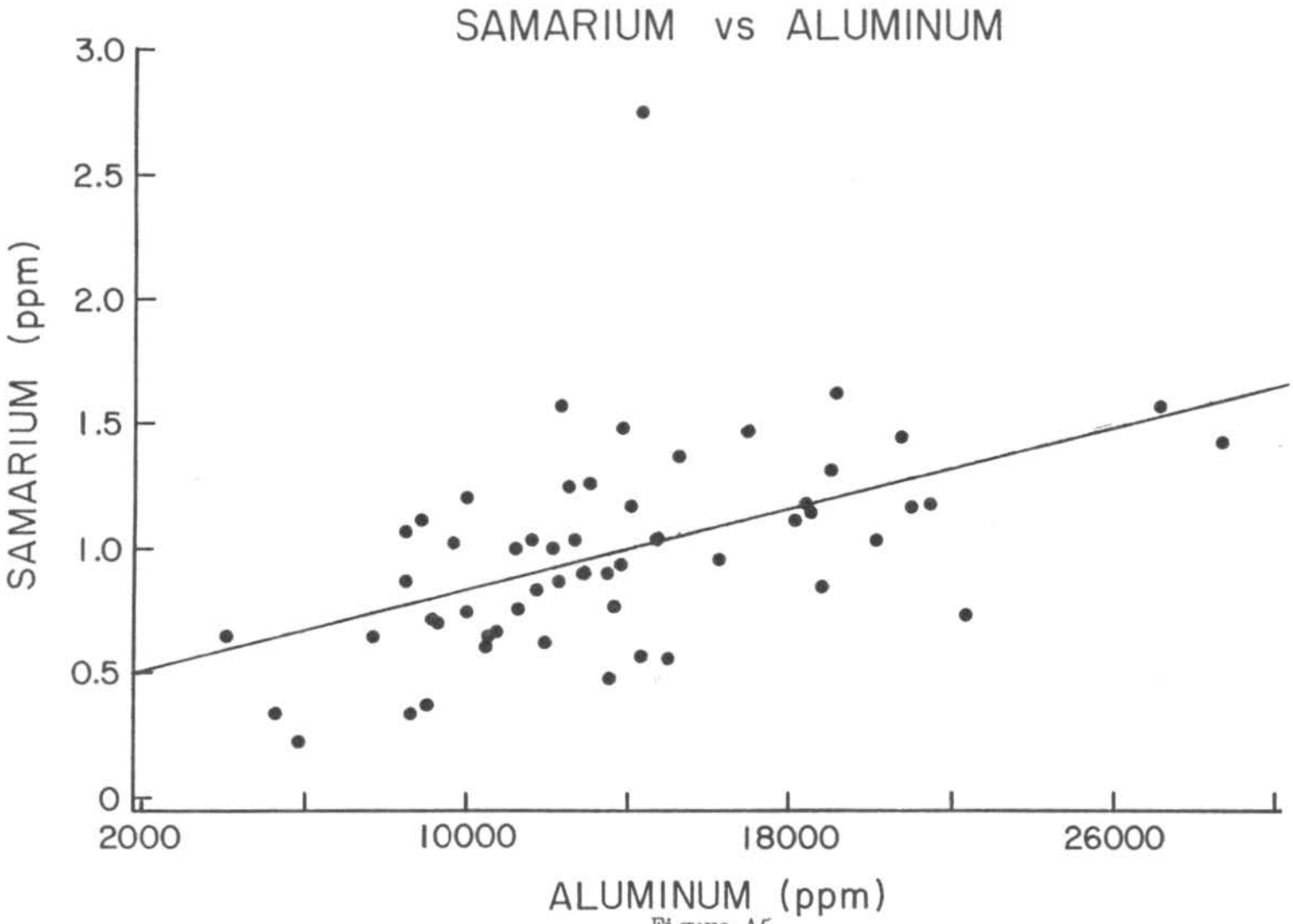
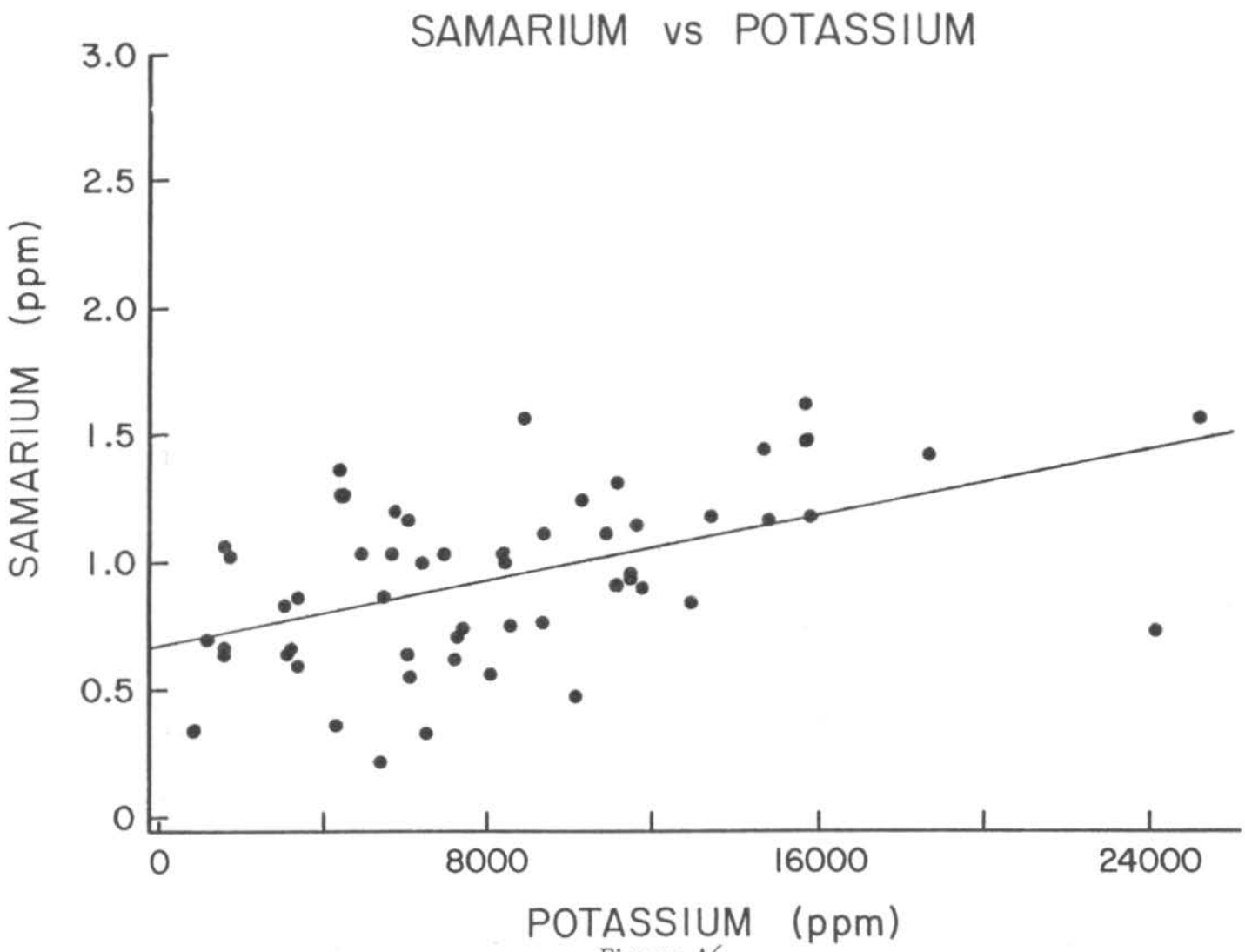

CERIUM vs POTASSIUM
CERIUM (ppm)
30
25
20
15
10
5
0
0
8000
16000
24000
POTASSIUM (ppm)

Figure A4


SAMARIUM vs ALUMINUM
SAMARIUM (ppm)
3.0
2.5
2.0
1.5
1.0
0.5
0
2000
10000
18000
26000
ALUMINUM (ppm)
Figure A5


SAMARIUM vs POTASSIUM
SAMARIUM (ppm)
3.0
2.5
2.0
1.5
1.0
0.5
0
0
8000
16000
24000
POTASSIUM (ppm)
Figure A6

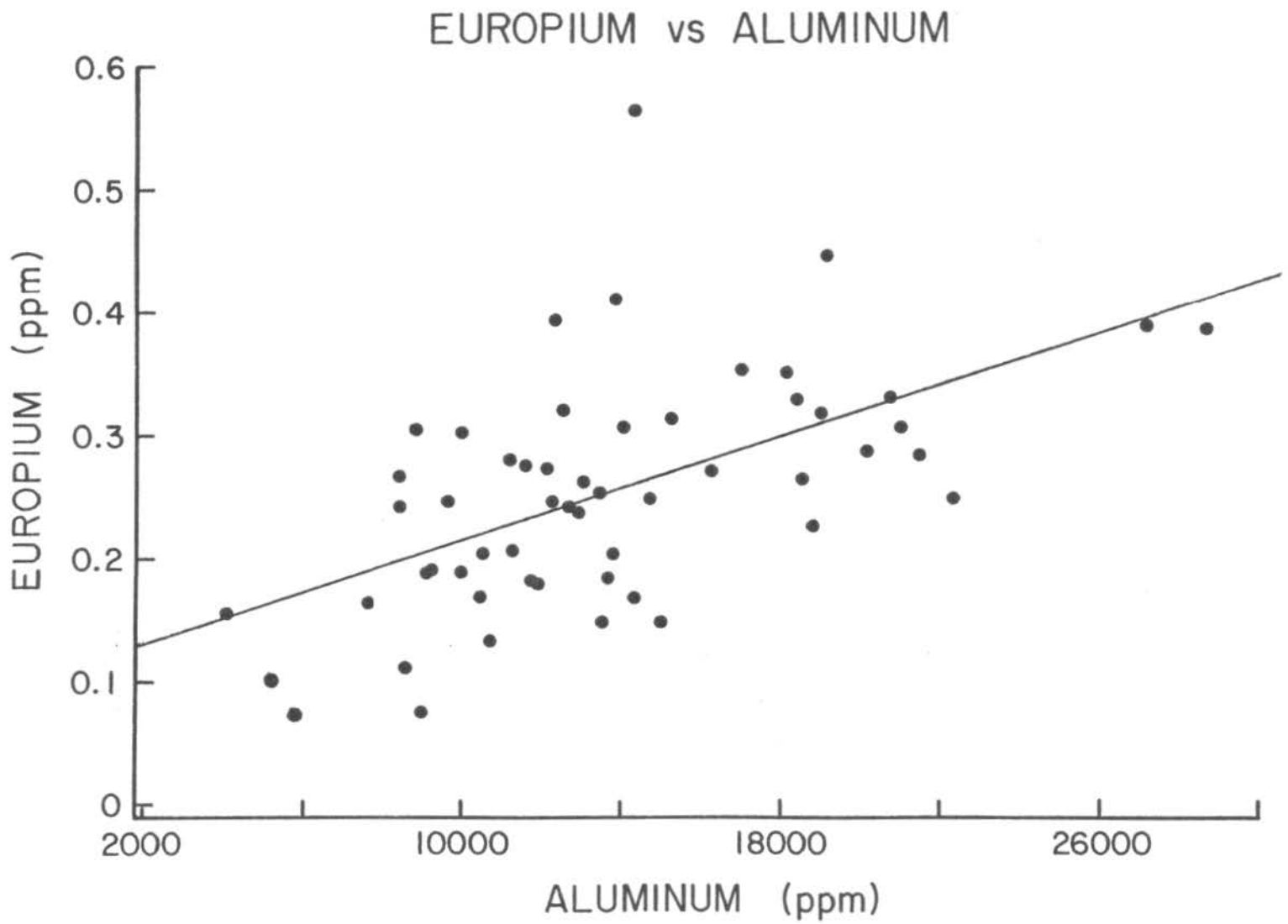

EUROPIUM vs ALUMINUM
EUROPIUM (ppm)
0.6
0.5
0.4
0.3
0.2
0.1
0
2000
10000
18000
26000
ALUMINUM (ppm)

Figure A7

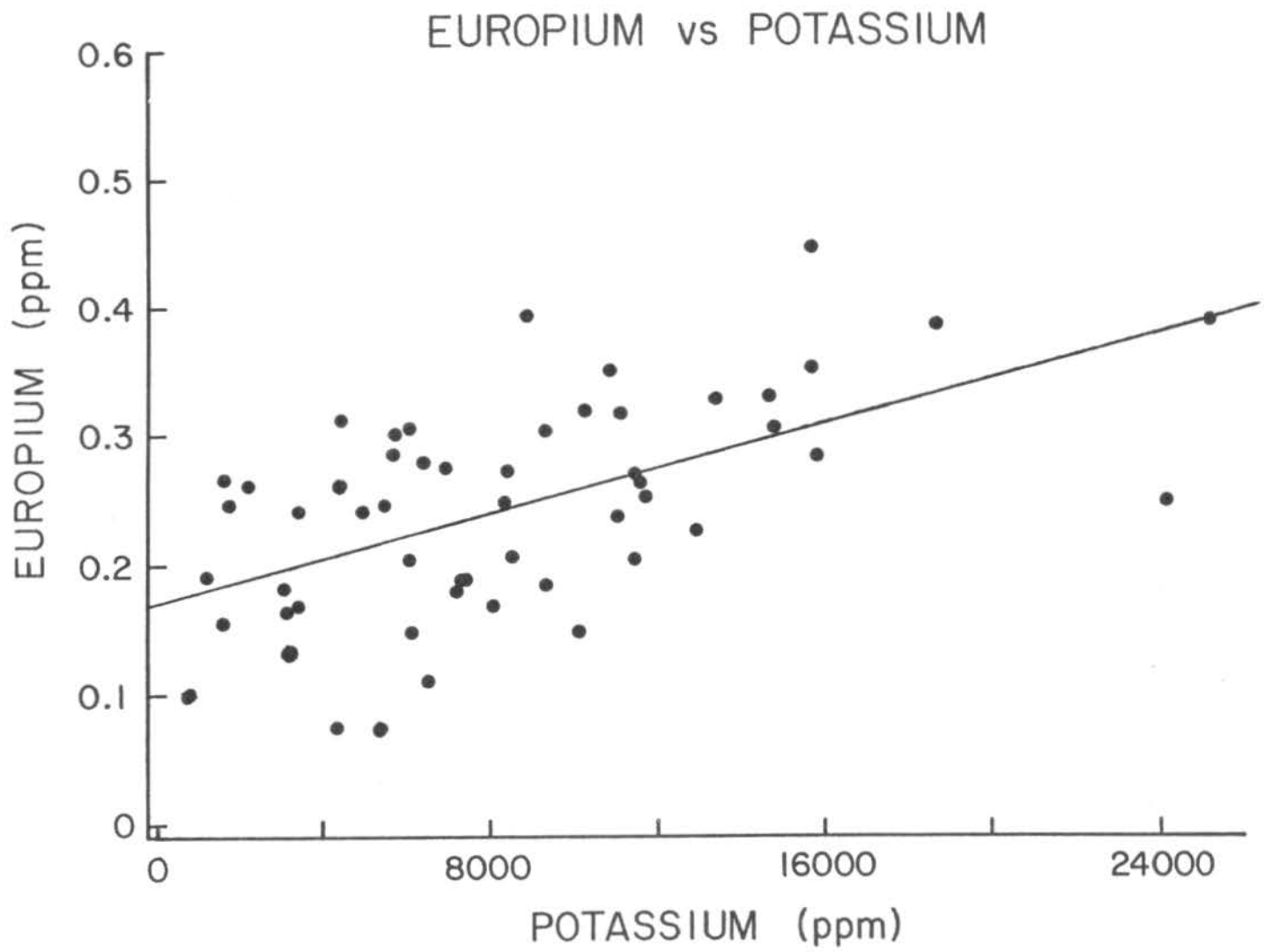

EUROPIUM vs POTASSIUM
EUROPIUM (ppm)
0.6
0.5
0.4
0.3
0.2
0.1
0
0
8000
16000
24000
POTASSIUM (ppm)

Figure A8

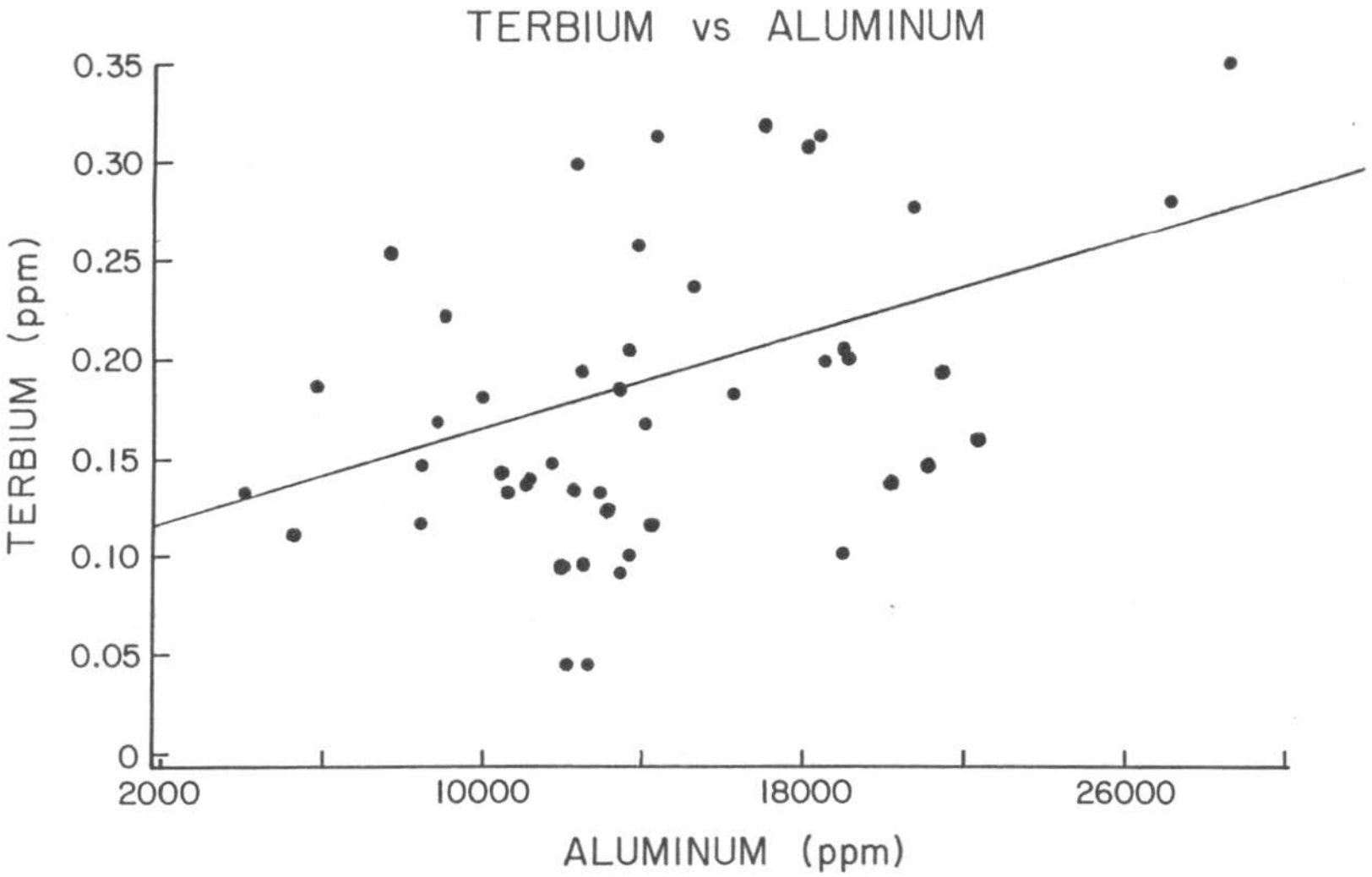

TERBIUM vs ALUMINUM
TERBIUM (ppm)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
2000
10000
18000
26000
ALUMINUM (ppm)

Figure A9

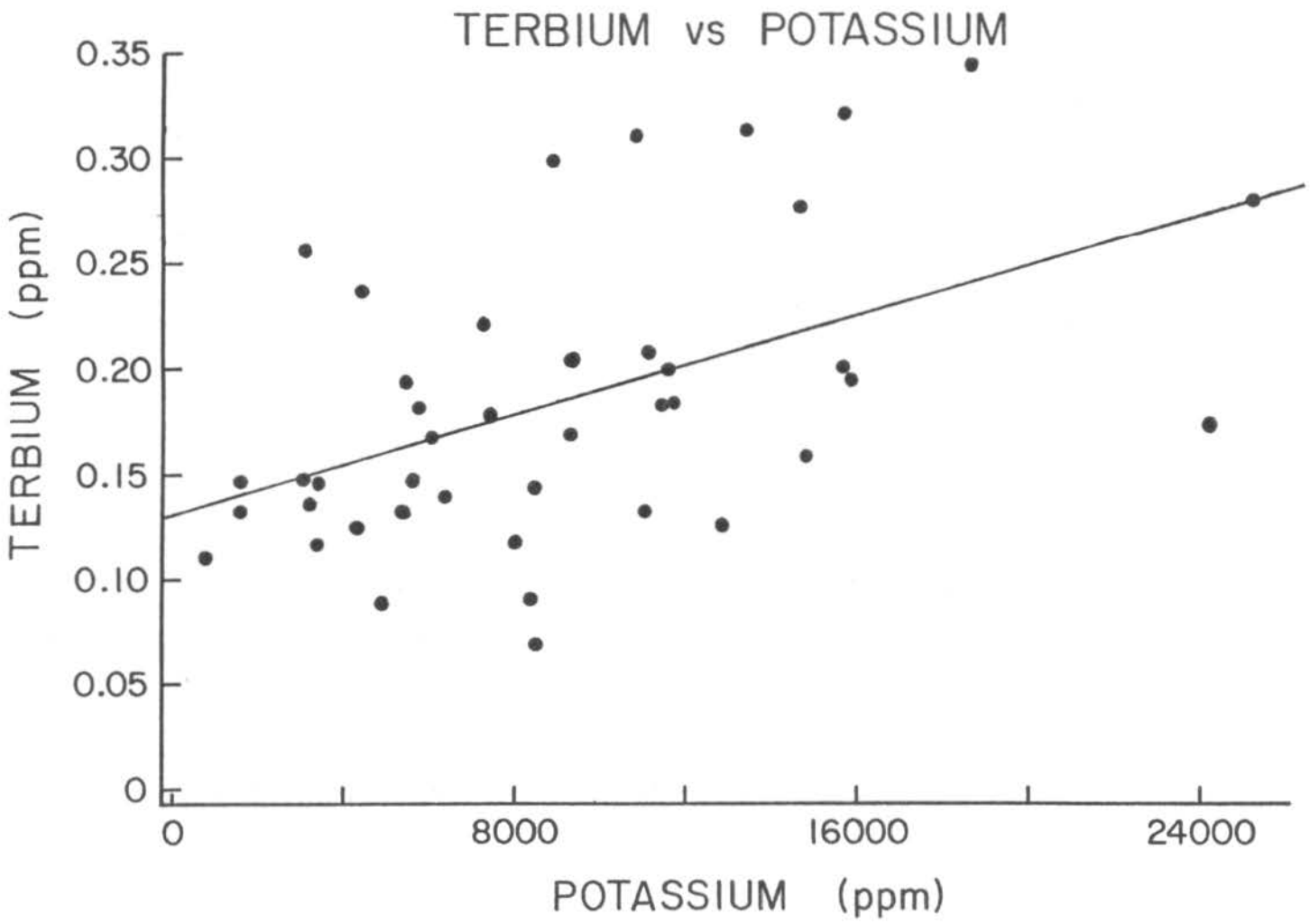

TERBIUM vs POTASSIUM
TERBIUM (ppm)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
0
8000
16000
24000
POTASSIUM (ppm)

Figure A10

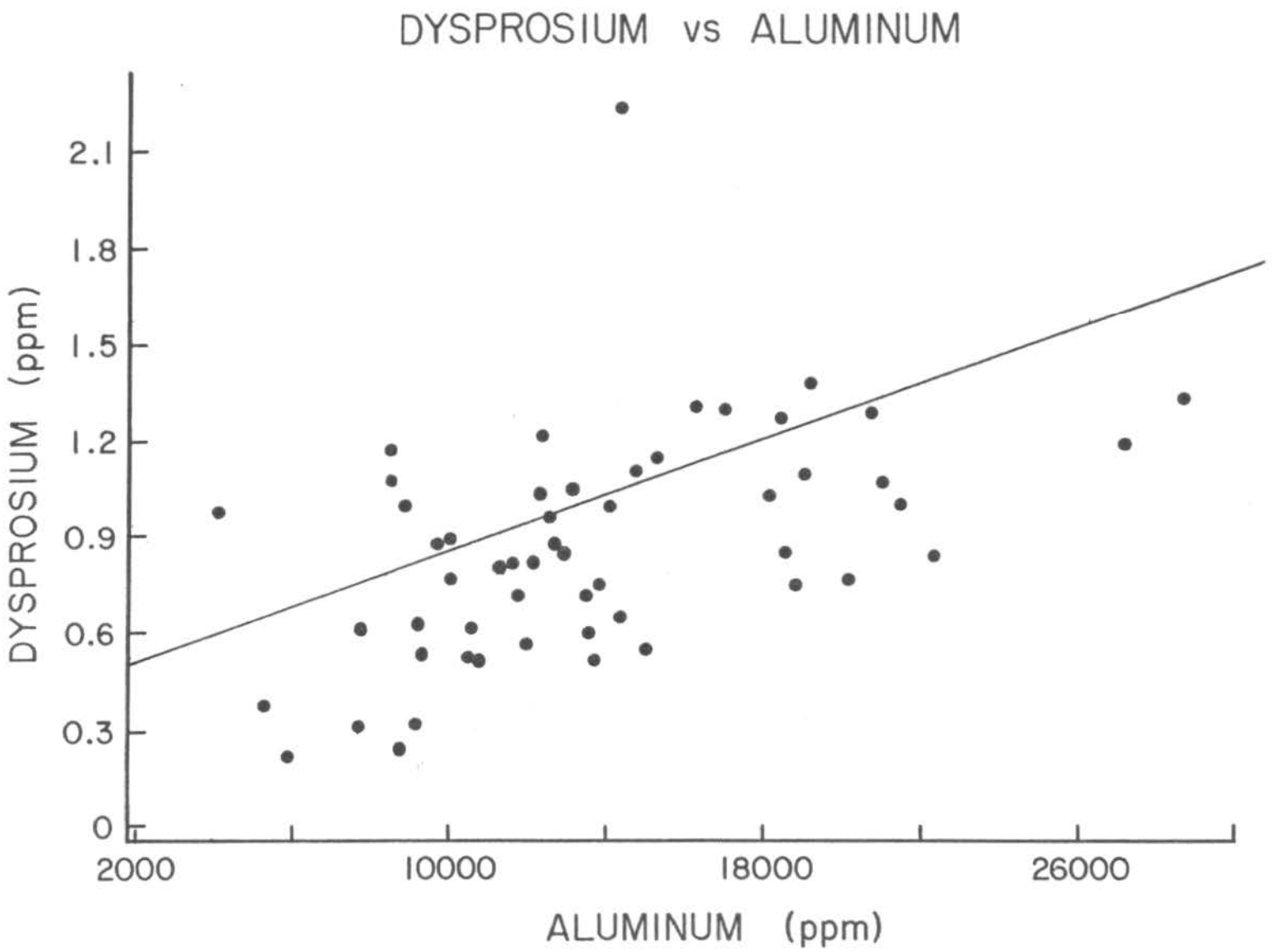

DYSPROSIUM vs ALUMINUM
DYSPROSIUM (ppm)
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0
2000
10000
18000
26000
ALUMINUM (ppm)

Figure A11

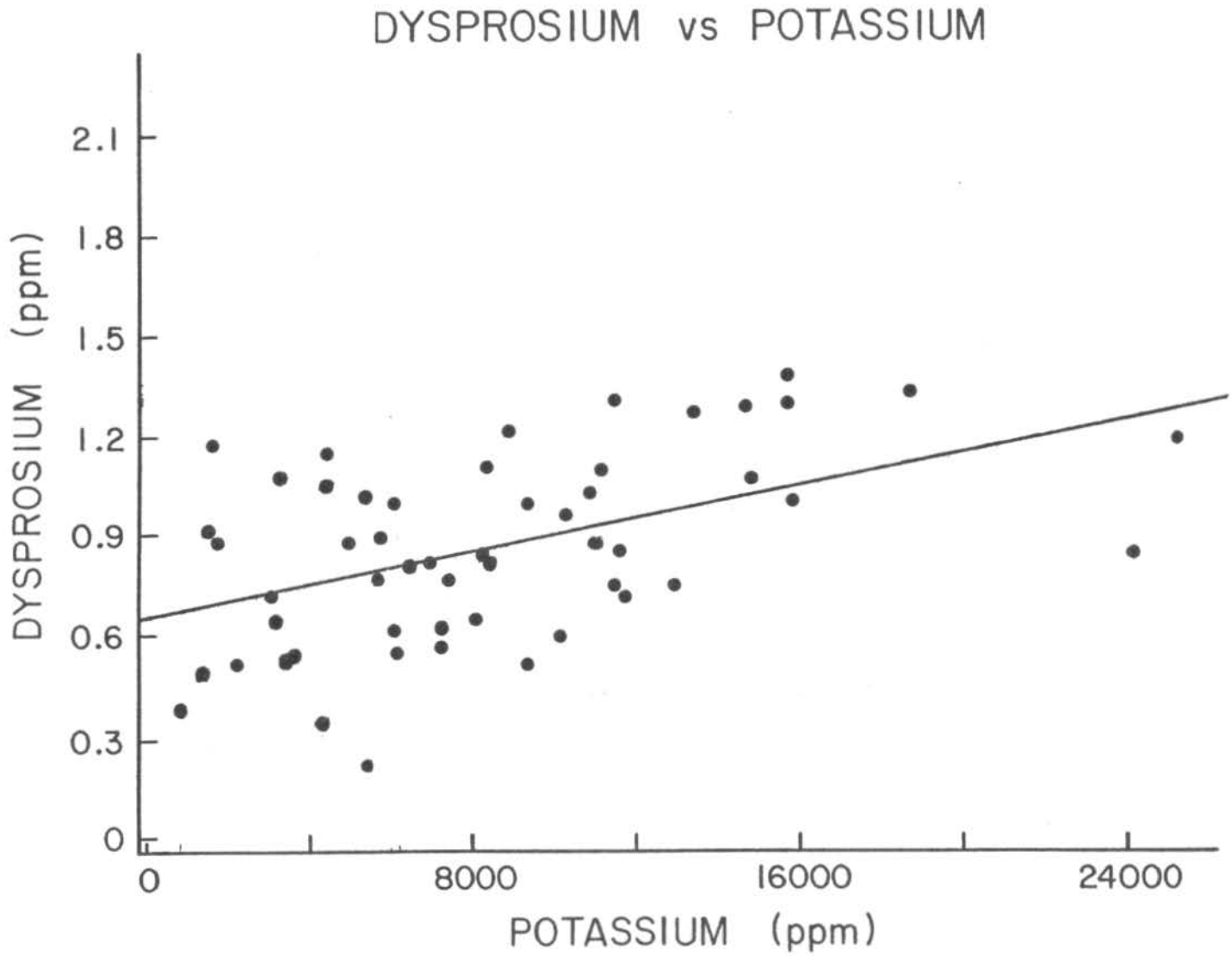

DYSPROSIUM vs POTASSIUM
DYSPROSIUM (ppm)
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0
0
8000
16000
24000
POTASSIUM (ppm)

Figure A12

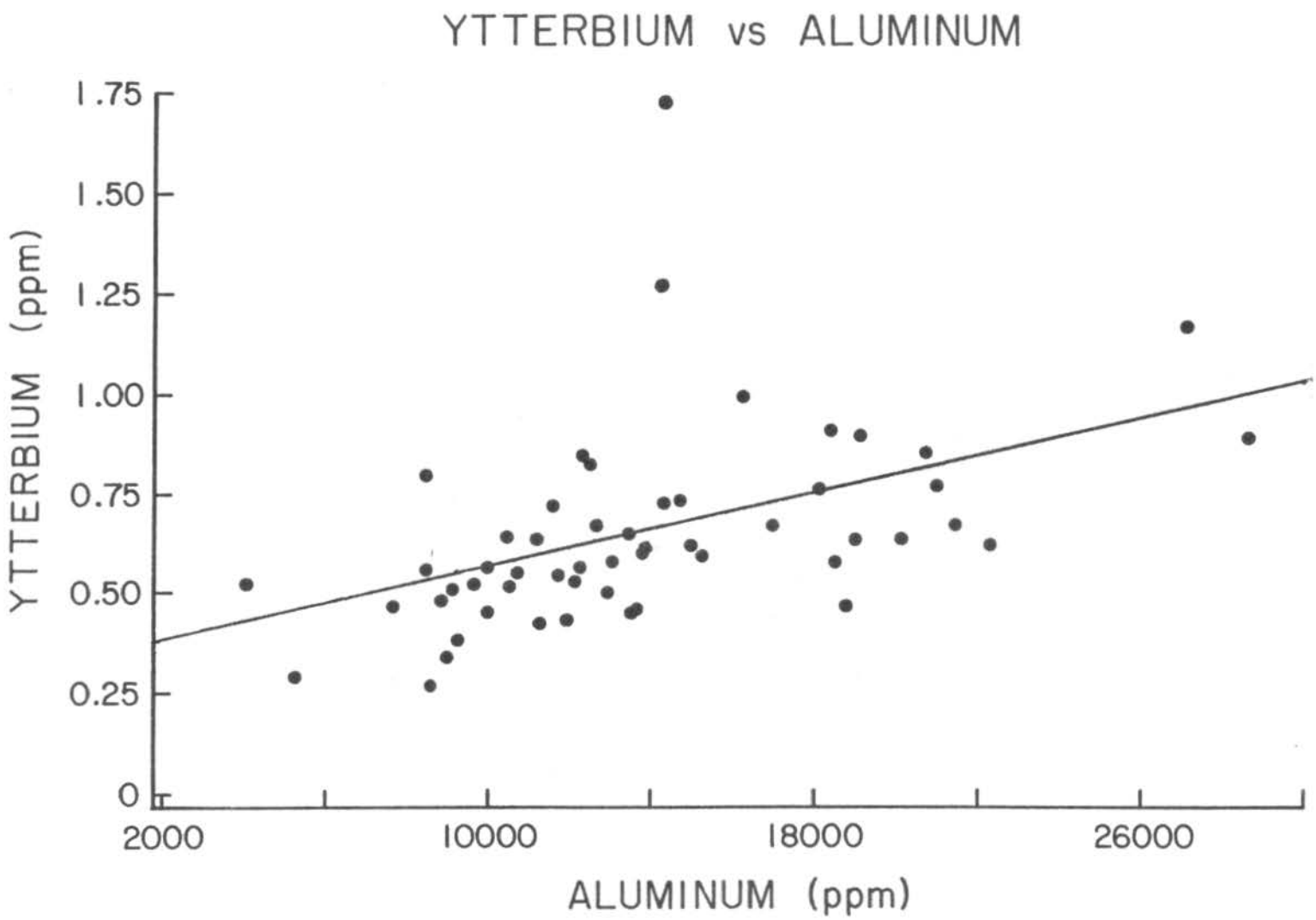

YTTERBIUM vs ALUMINUM
YTTERBIUM (ppm)
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0
2000
10000
18000
26000
ALUMINUM (ppm)

Figure A13

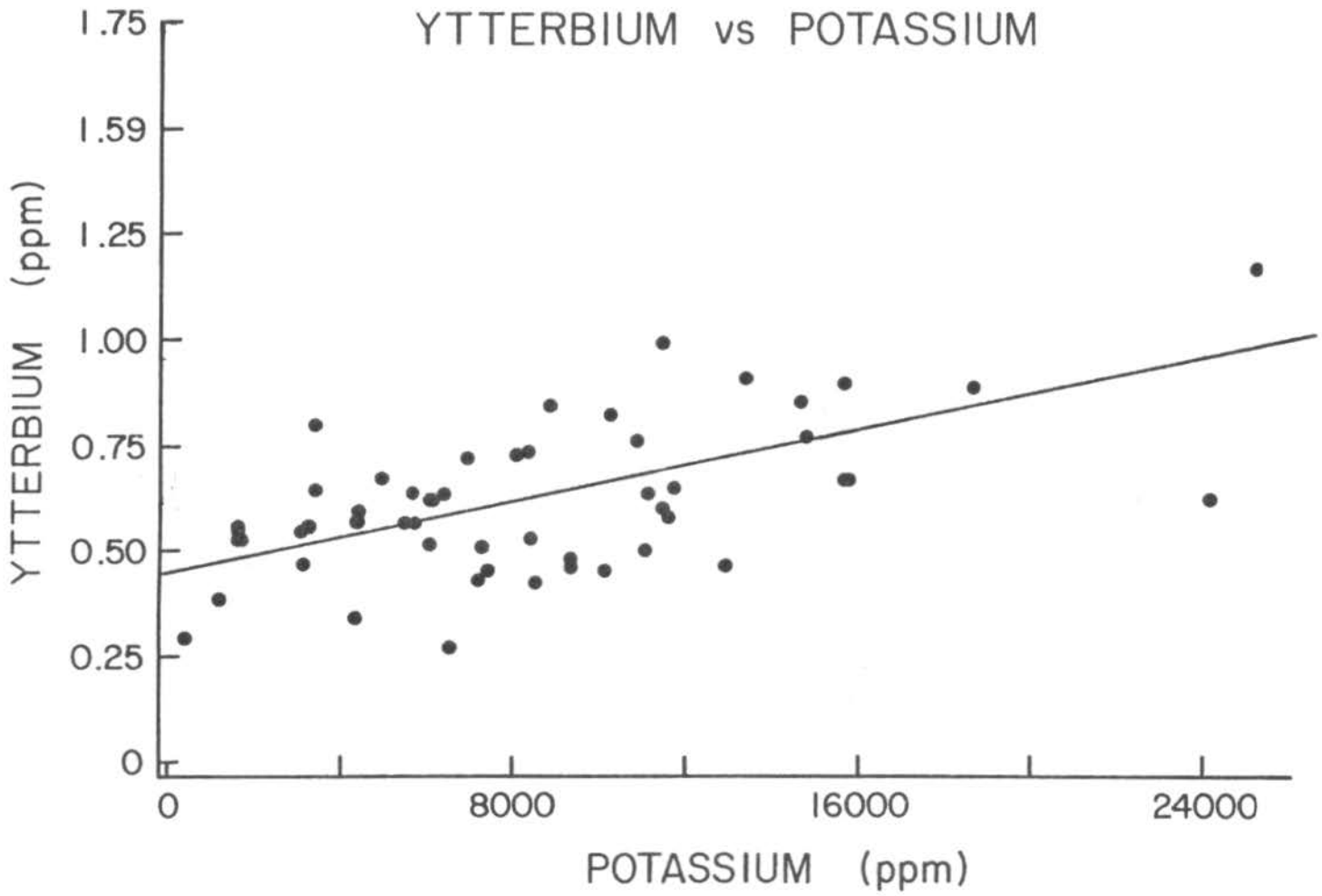
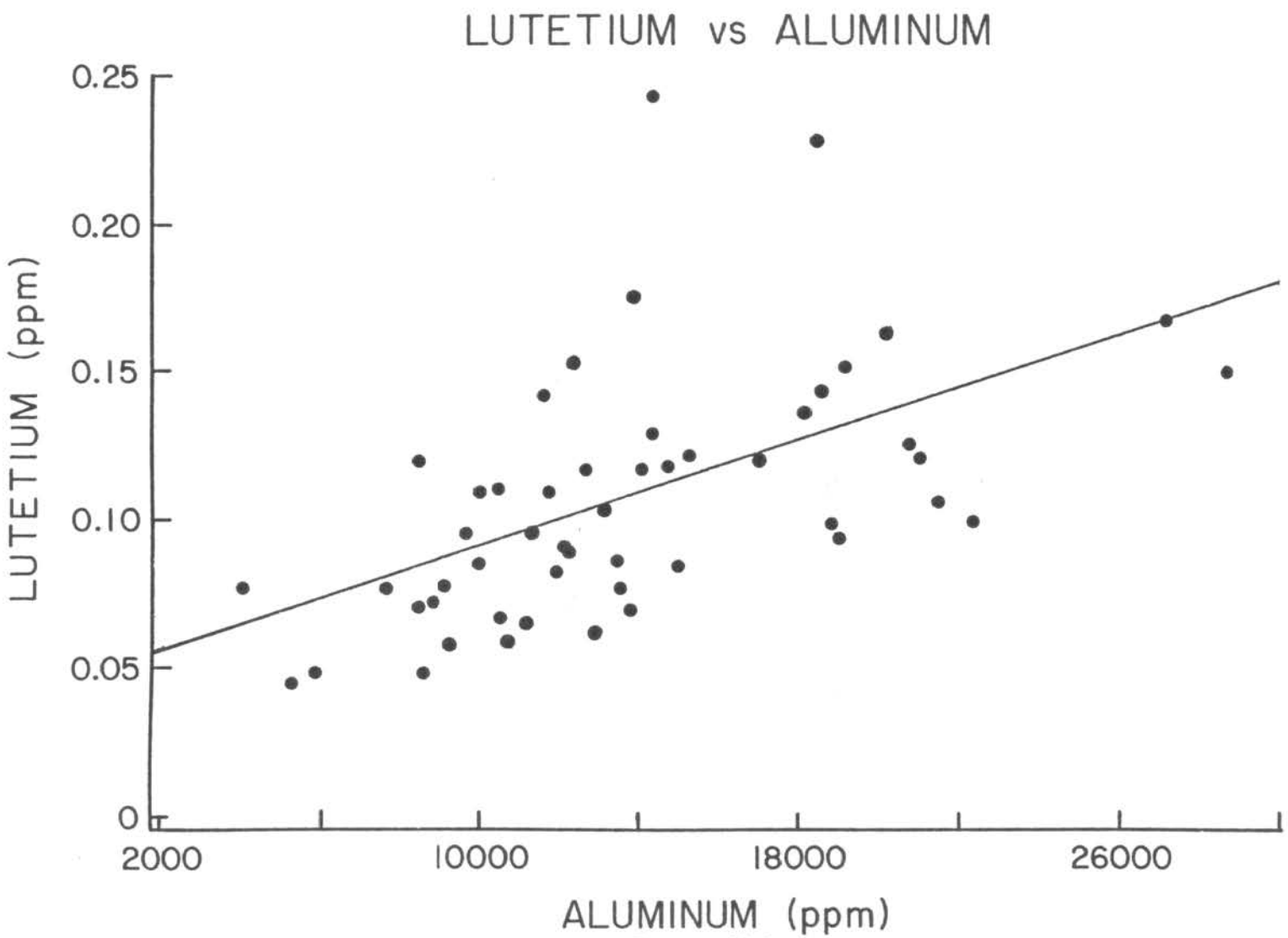

YTTERBIUM vs POTASSIUM
YTTERBIUM (ppm)
1.75
1.59
1.25
1.00
0.75
0.50
0.25
0
0
8000
16000
24000
POTASSIUM (ppm)

Figure A14


LUTETIUM vs ALUMINUM
LUTETIUM (ppm)
0.25
0.20
0.15
0.10
0.05
0
2000
10000
18000
26000
ALUMINUM (ppm)
Figure A15

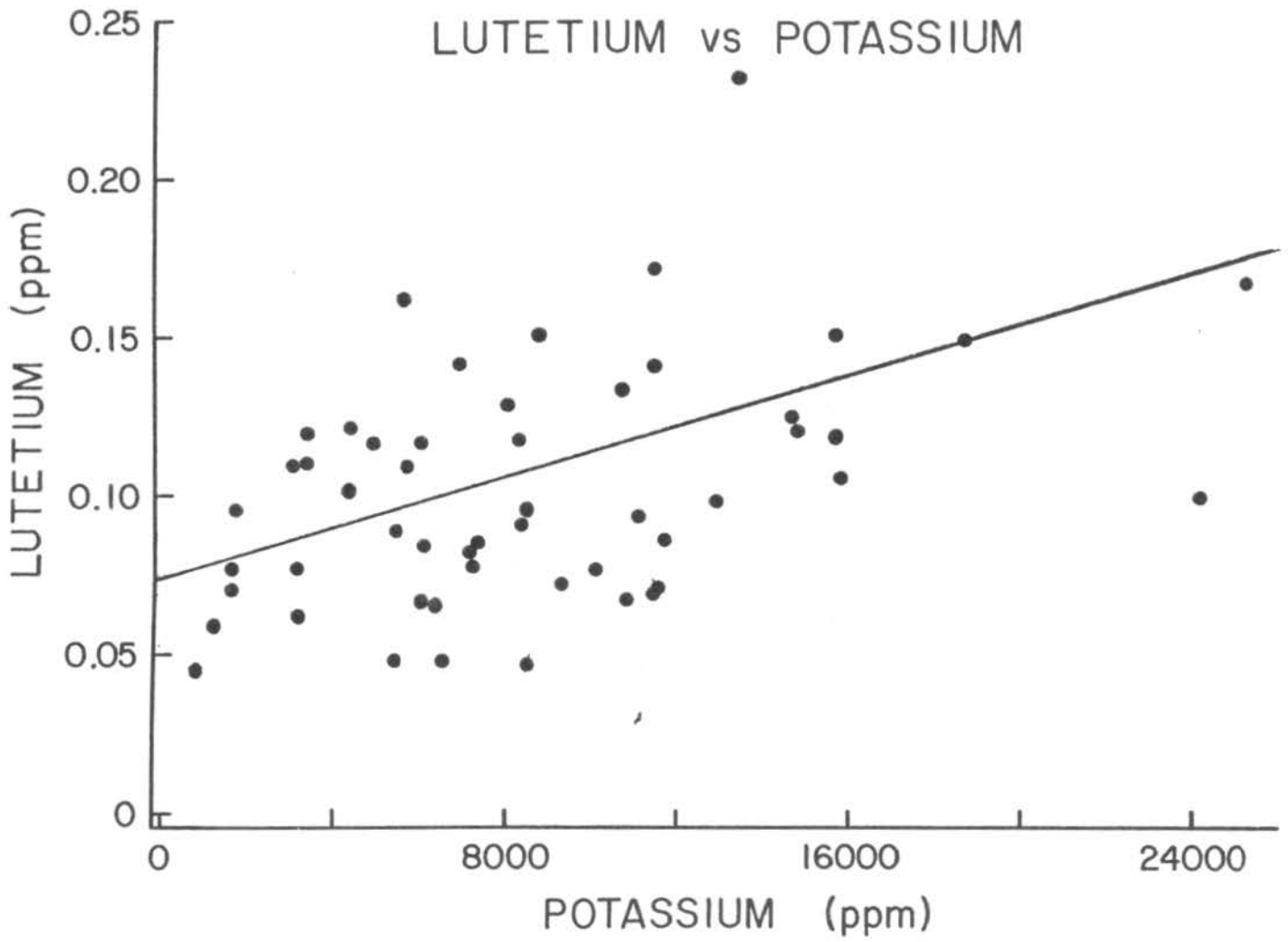

LUTETIUM vs POTASSIUM
LUTETIUM (ppm)
0.25
0.20
0.15
0.10
0.05
0
0
8000
16000
24000
POTASSIUM (ppm)

Figure A16

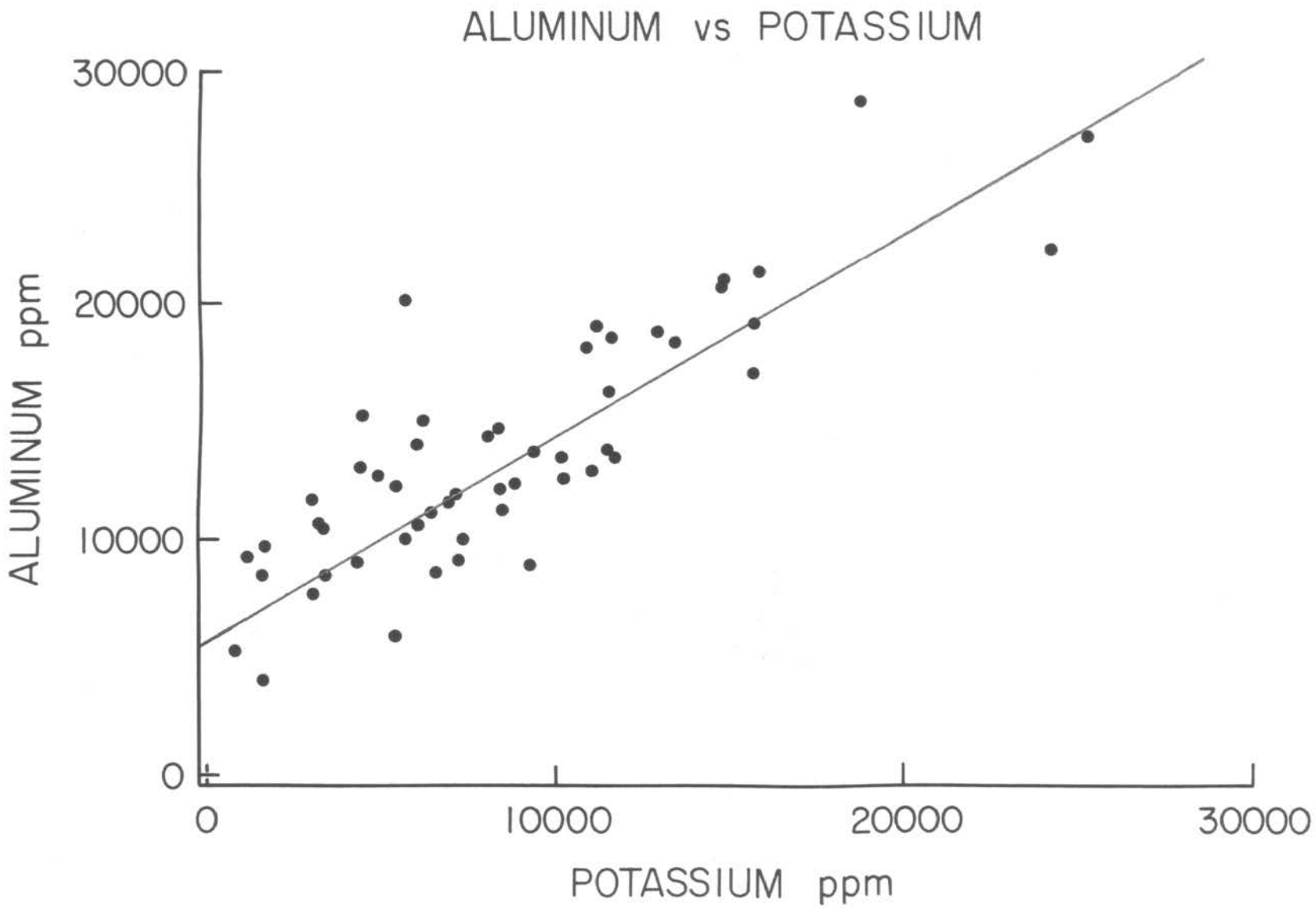

ALUMINUM vs POTASSIUM
ALUMINUM ppm
30000
20000
10000
0
0
10000
20000
30000
POTASSIUM ppm

Figure A17

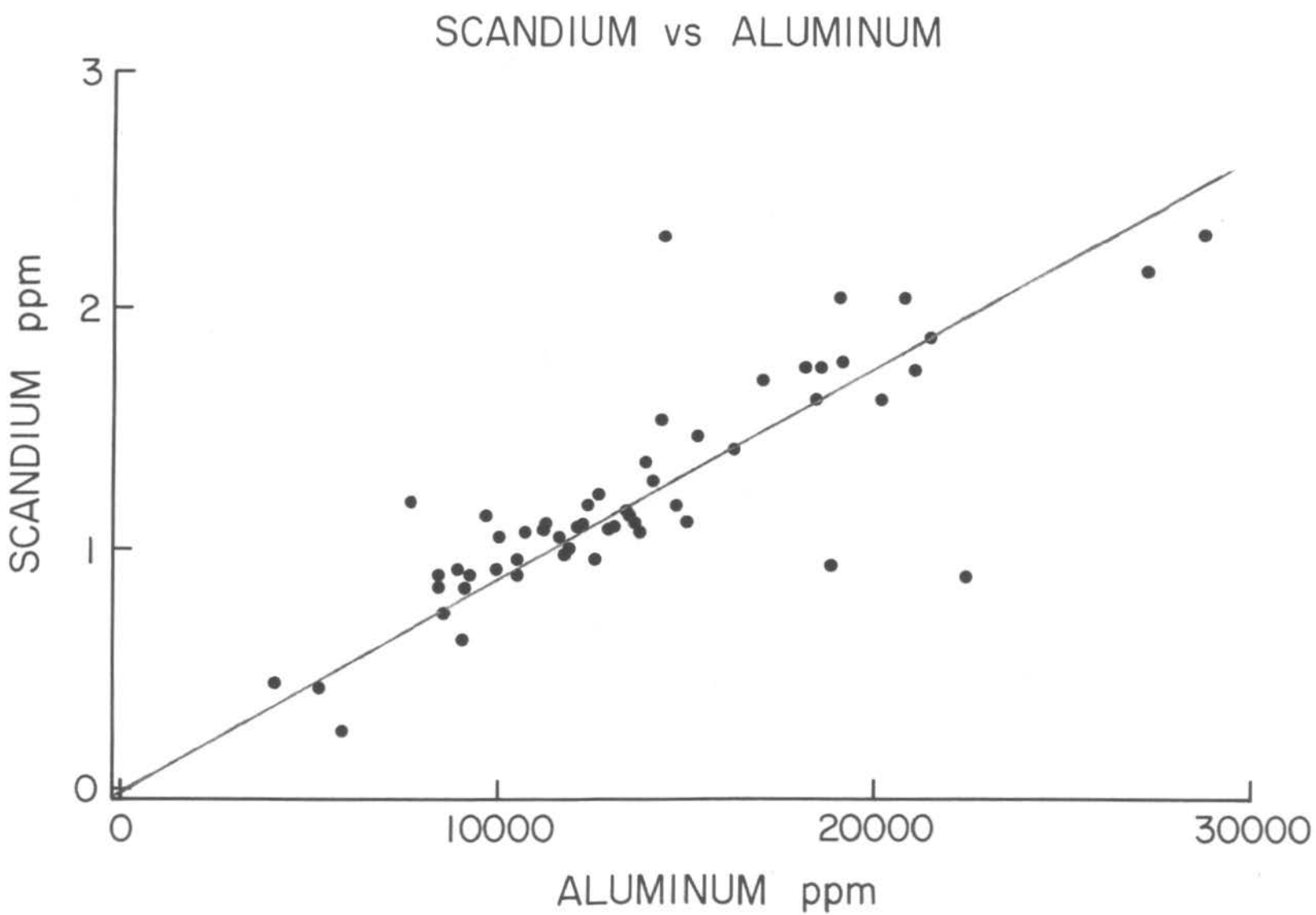

SCANDIUM vs ALUMINUM
SCANDIUM ppm
3
2
1
0
0
10000
20000
30000
ALUMINUM ppm

Figure A18

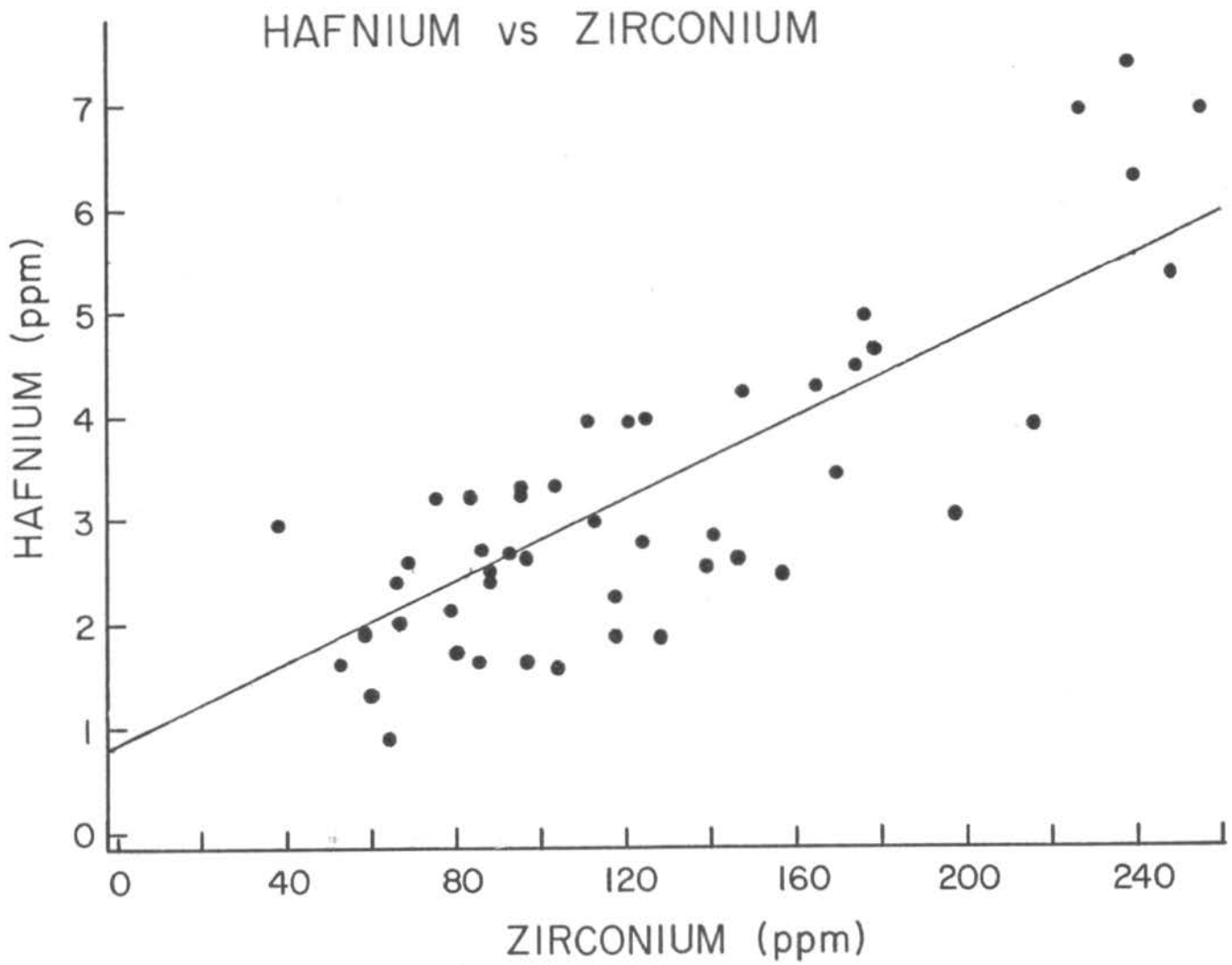

HAFNIUM vs ZIRCONIUM
HAFNIUM (ppm)
0
1
2
3
4
5
6
7
0
40
80
120
160
200
240
ZIRCONIUM (ppm)

Figure A19

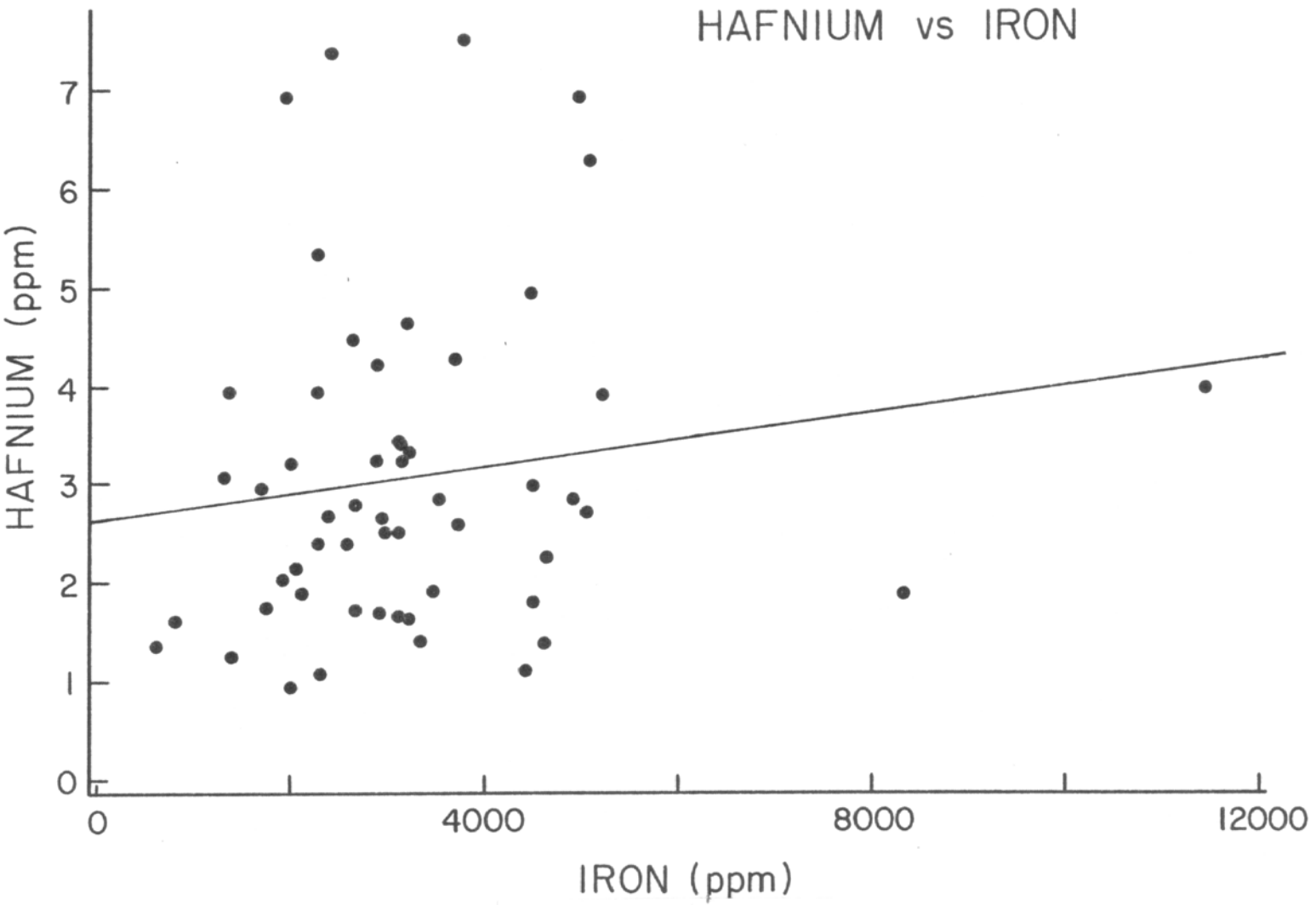

HAFNIUM vs IRON
HAFNIUM (ppm)
0
1
2
3
4
5
6
7
0
4000
8000
12000
IRON (ppm)

Figure A20

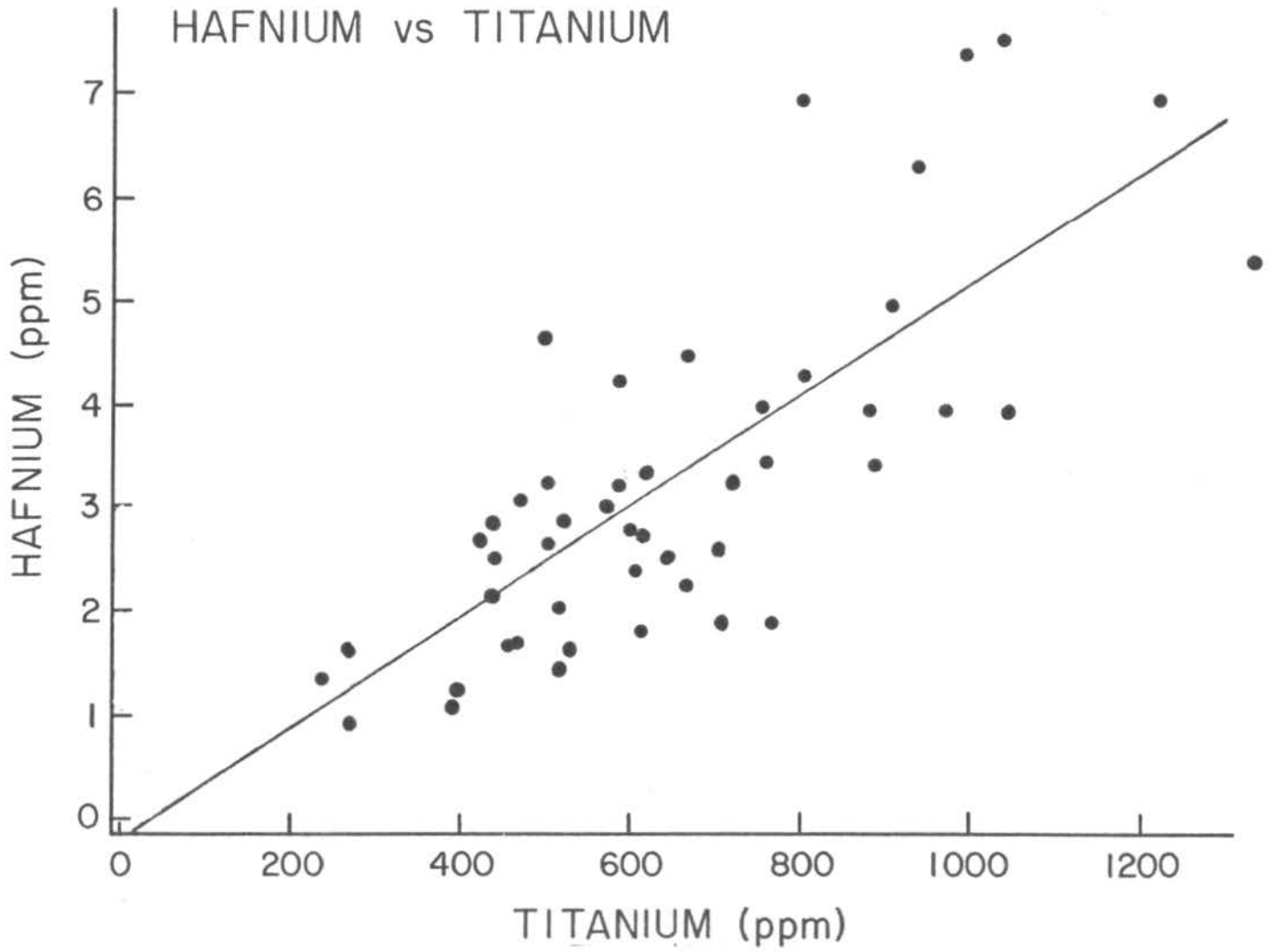
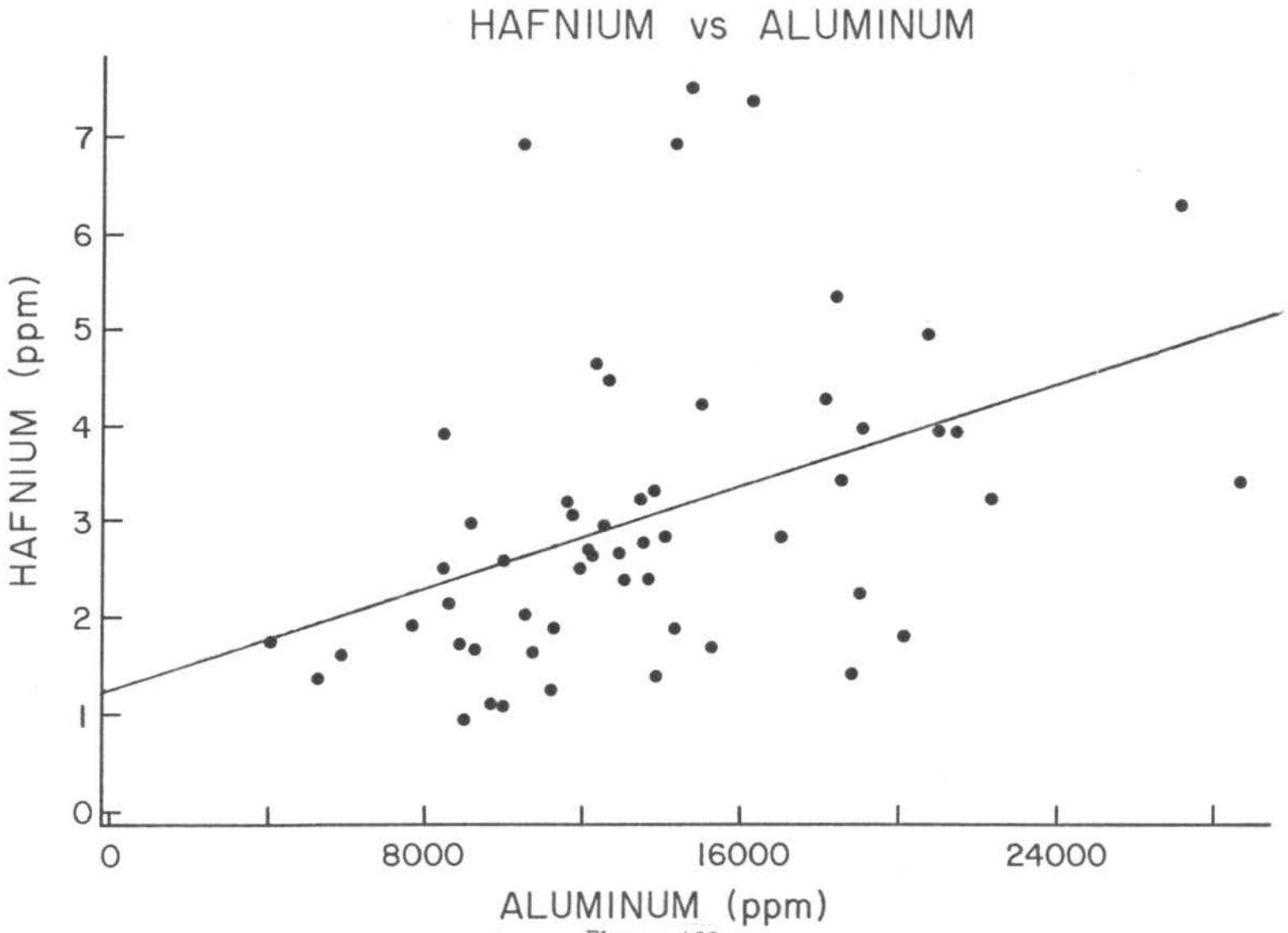
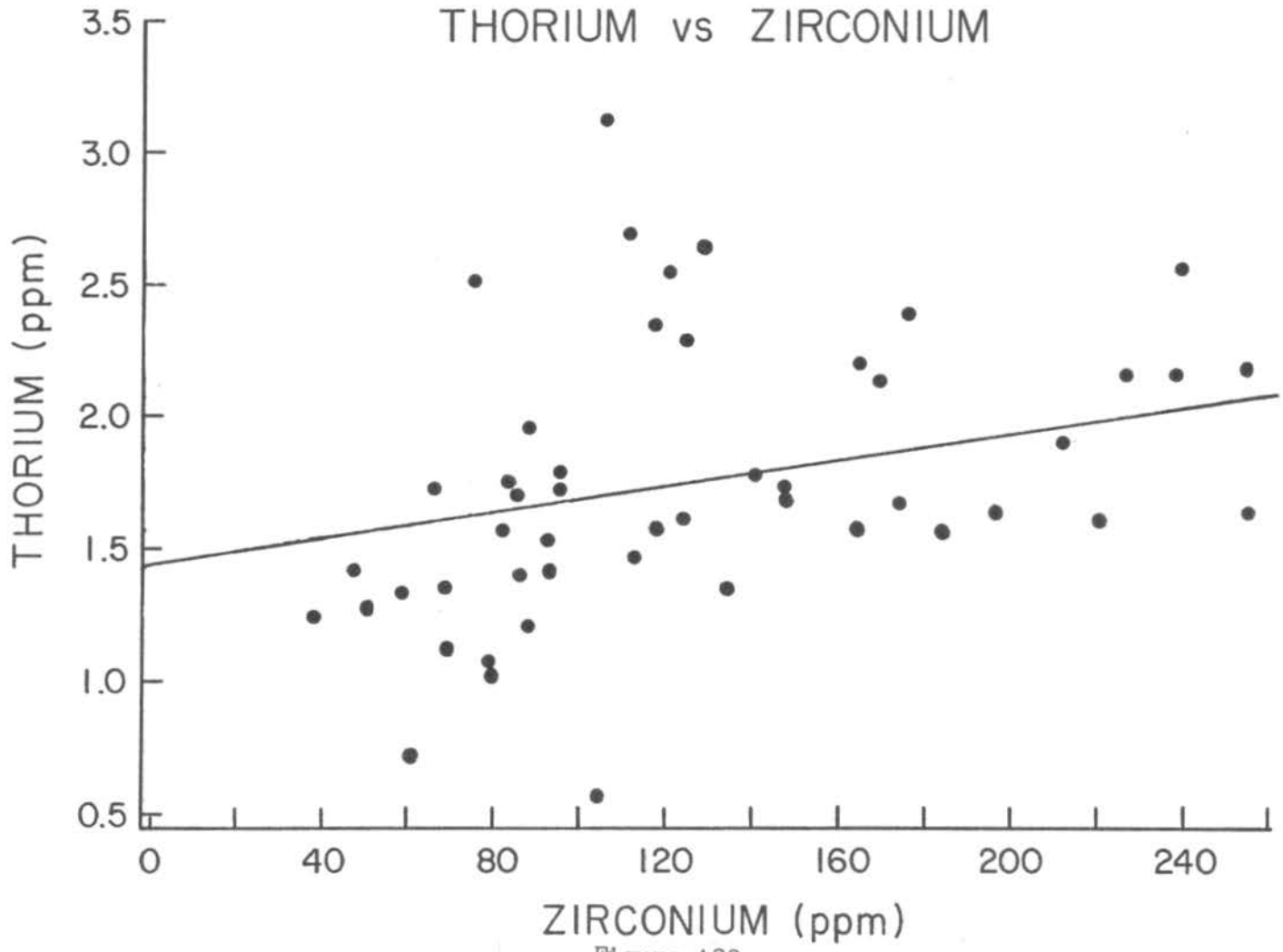

HAFNIUM vs TITANIUM
HAFNIUM (ppm)
0
1
2
3
4
5
6
7
0
200
400
600
800
1000
1200
TITANIUM (ppm)

Figure A21


HAFNIUM vs ALUMINUM
HAFNIUM (ppm)
0
1
2
3
4
5
6
7
0
8000
16000
24000
ALUMINUM (ppm)
Figure A22


THORIUM vs ZIRCONIUM
THORIUM (ppm)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
40
80
120
160
200
240
ZIRCONIUM (ppm)
Figure A23

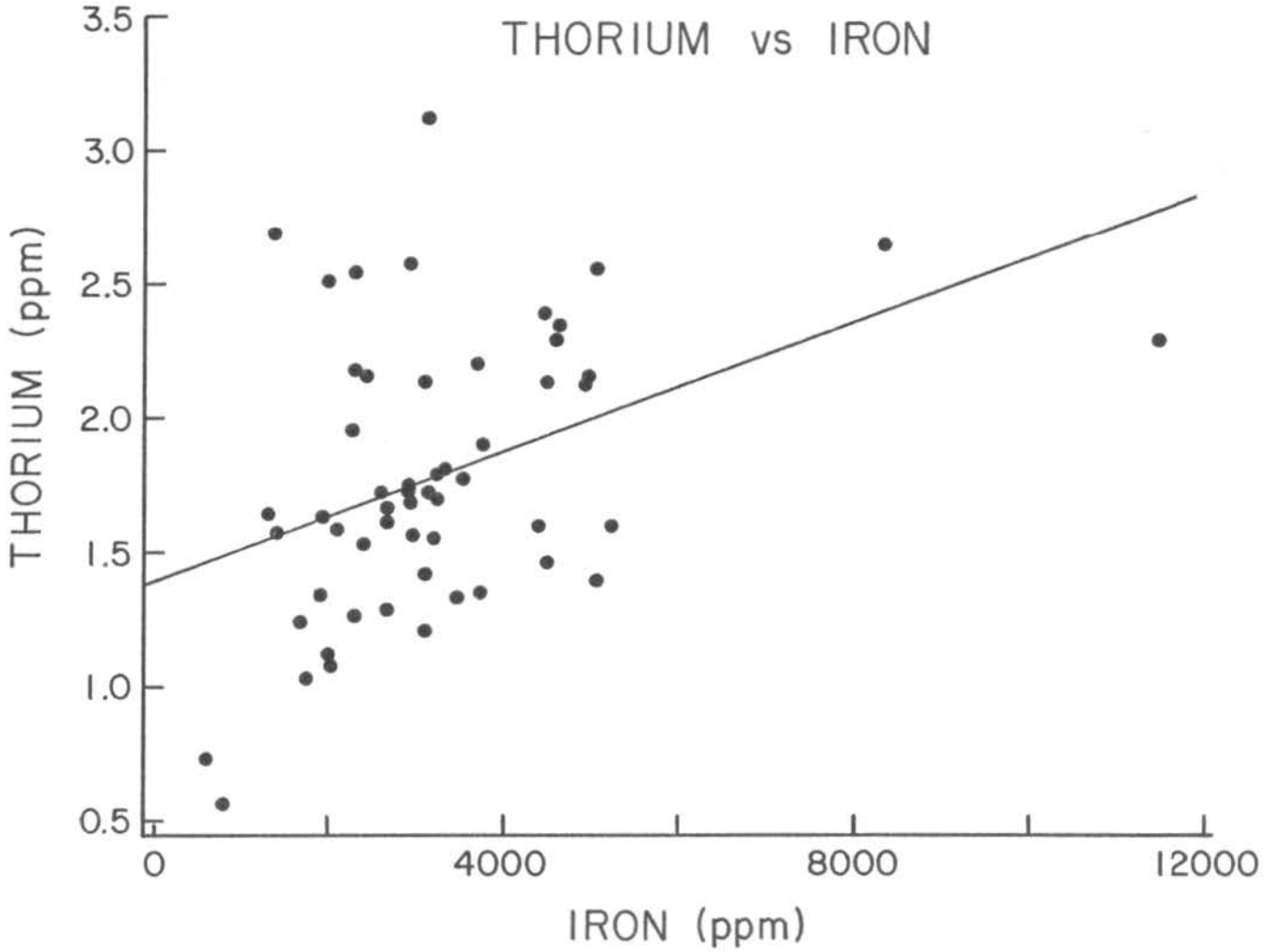

THORIUM vs IRON
THORIUM (ppm)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
4000
8000
12000
IRON (ppm)

Figure A24

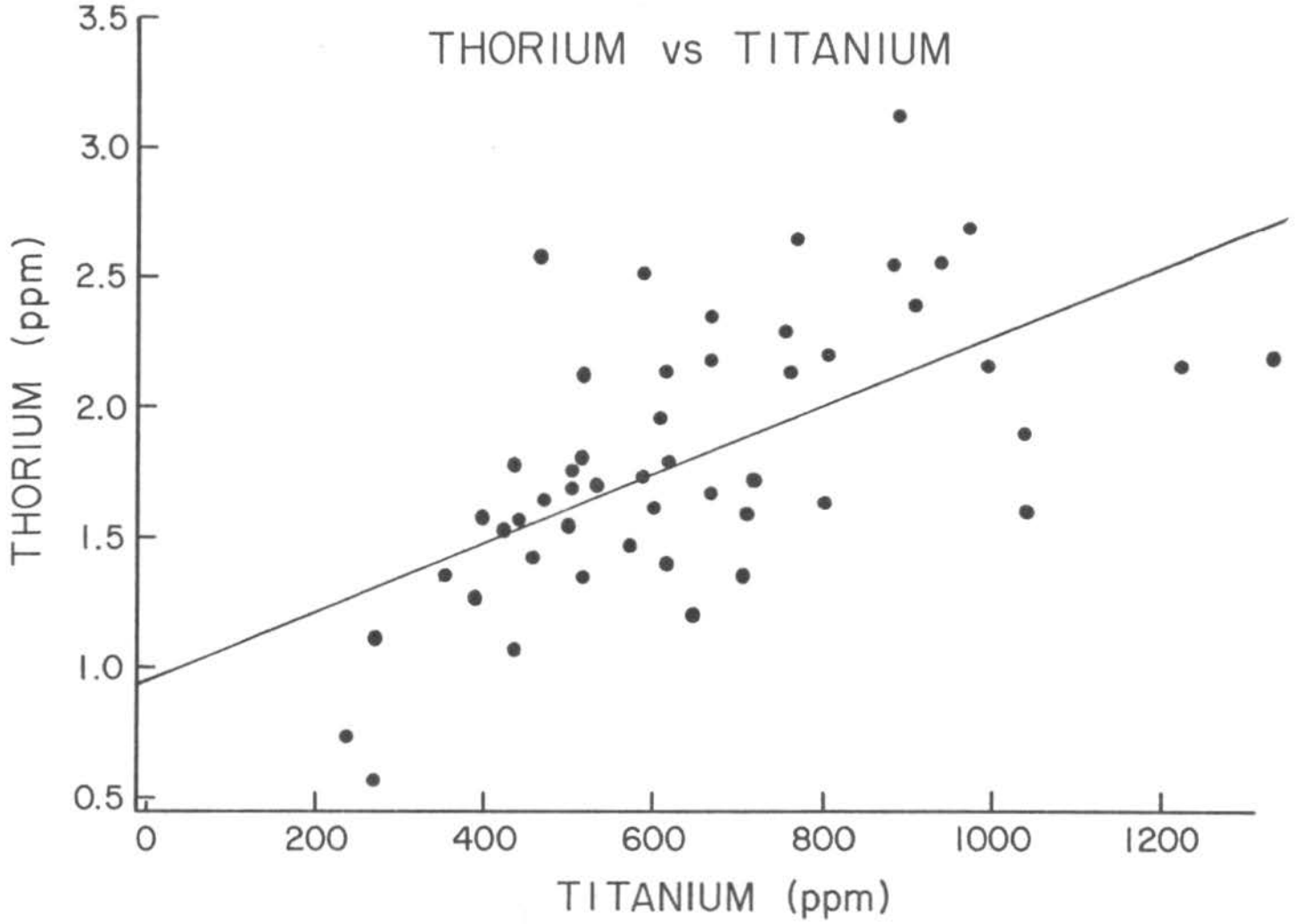
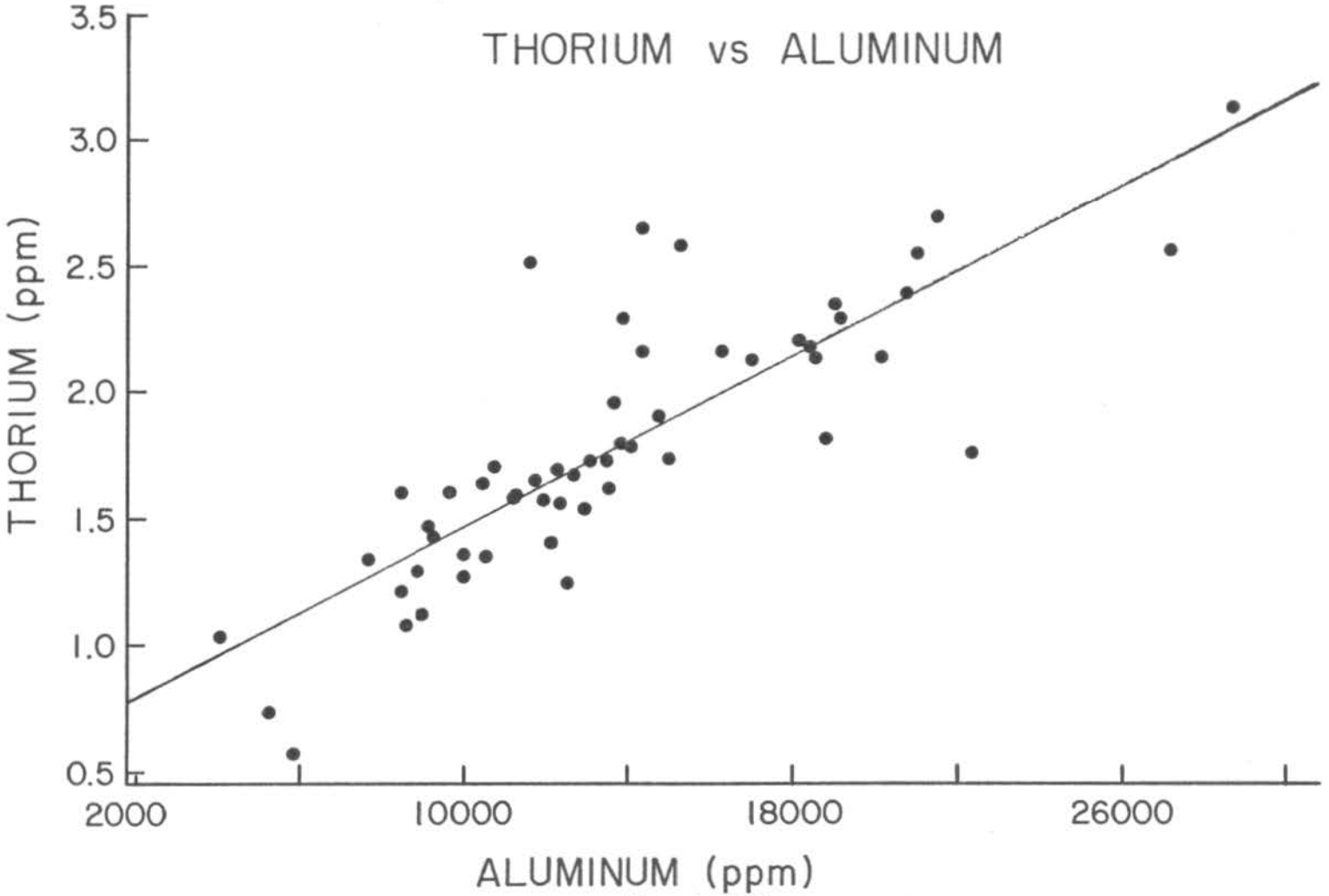

THORIUM vs TITANIUM
THORIUM (ppm)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
200
400
600
800
1000
1200
TITANIUM (ppm)

Figure A25


THORIUM vs ALUMINUM
THORIUM (ppm)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
2000
10000
18000
26000
ALUMINUM (ppm)
Figure A26

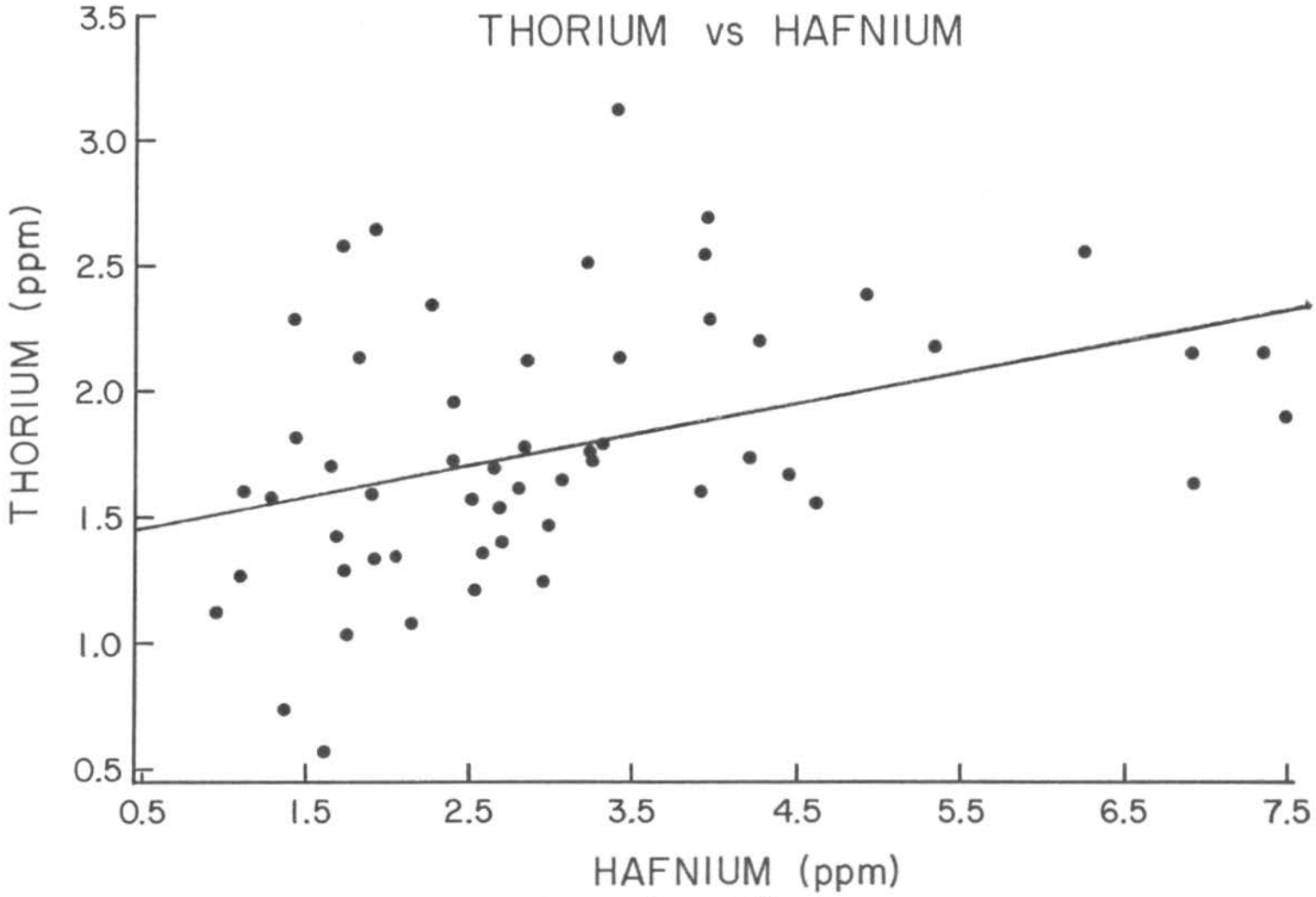

THORIUM vs HAFNIUM
THORIUM (ppm)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.5
1.5
2.5
3.5
4.5
5.5
6.5
7.5
HAFNIUM (ppm)

Figure A27

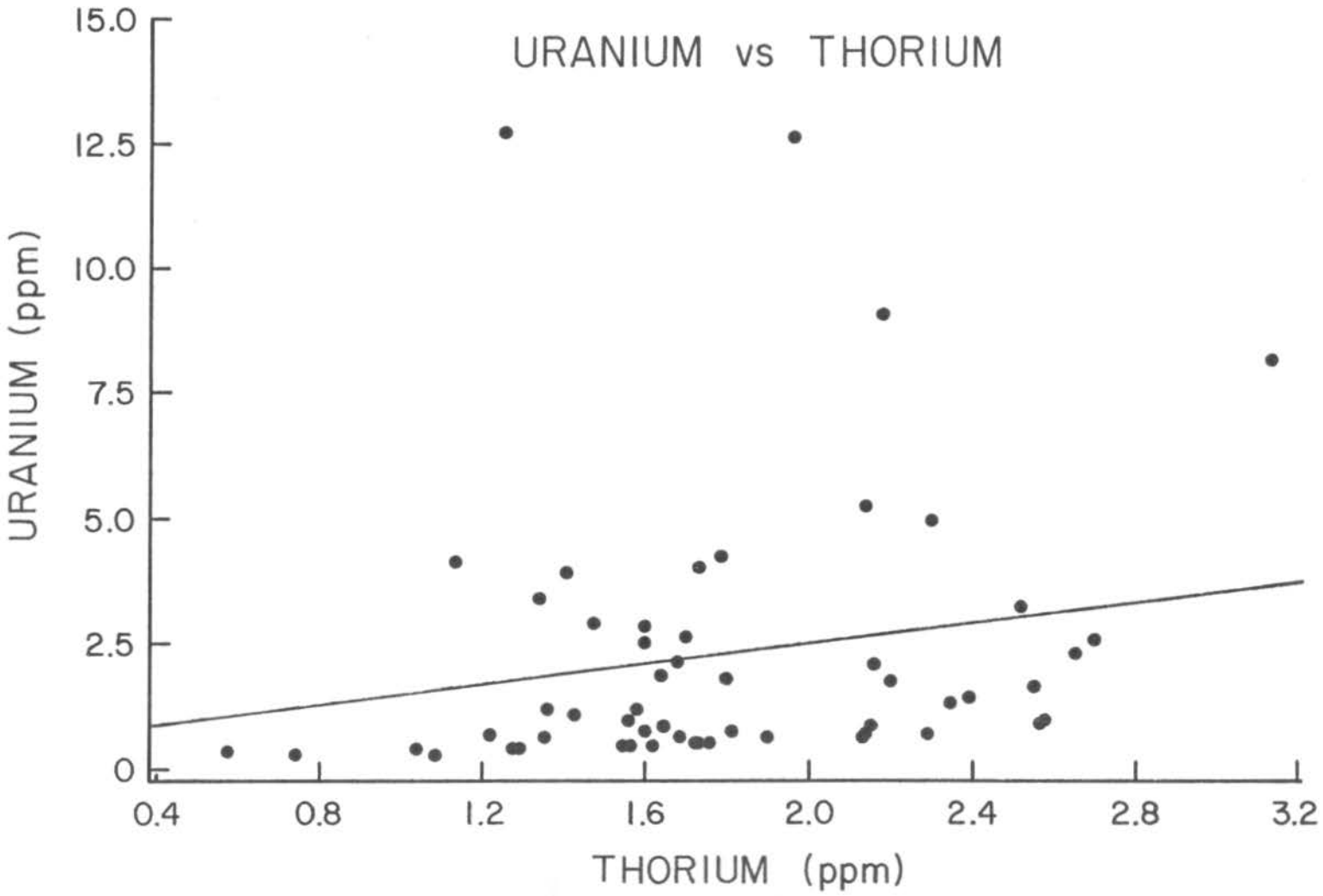
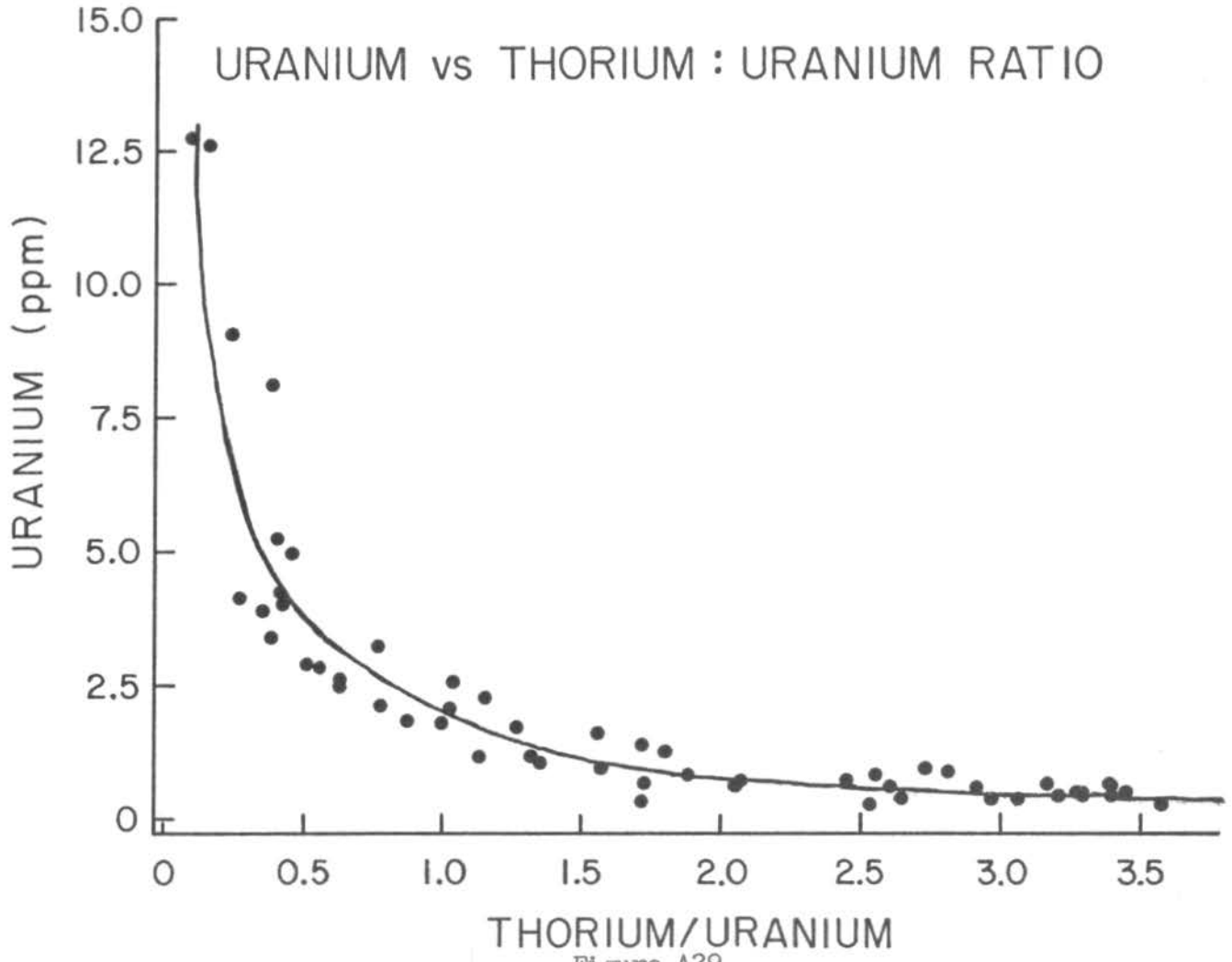

URANIUM vs THORIUM
URANIUM (ppm)
15.0
12.5
10.0
7.5
5.0
2.5
0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
THORIUM (ppm)

Figure A28


URANIUM vs THORIUM : URANIUM RATIO
URANIUM (ppm)
15.0
12.5
10.0
7.5
5.0
2.5
0
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
THORIUM/URANIUM
Figure A29

APPENDIX III: INAA ANALYSES

	6200360	6200370	6200380
Na- 24	1795 + - 61	518 + - 25	51.7 + - 6.4
Mg- 27	2740 + - 330	6140 + - 530	< 240
Al- 28	8810 + - 480	13690 + - 660	6520 + - 380
Cl- 38	< 25	< 24	30.2 + - 5.2
Ca- 49	< 260	20200 + - 1600	< 230
Ti- 51	511 + - 70	< 280	317 + - 39
V - 52	38.0 + - 2.4	15.9 + - 1.6	2.03 + - 0.52
Mn- 56	40.8 + - 1.5	321 + - 11	4.35 + - 0.23
Cu- 66	< 82	< 87	< 31
Sr- 87	< 78	< 130	97 + - 18
In-116	< 0.046	< 0.062	< 0.020
I -123	< 5.1	< 8.7	< 2.0
Ba-139	3150 + - 170	745 + - 48	399 + - 25
Dy-165	< 0.38	0.78 + - 0.11	0.409 + - 0.052
U -235	1.171 + - 0.033	2.254 + - 0.063	0.3430 + - 0.0096
K - 42	1630 + - 240	2570 + - 280	780 + - 140
Ga- 72	< 5.1	< 2.8	< 1.6
As- 76	0.99 + - 0.17	0.72 + - 0.11	42.1 + - 3.1
Br- 82	< 0.62	< 0.34	0.56 + - 0.13
Mo- 99	< 4.4	< 2.1	< 2.0
Sb-122	< 0.14	0.148 + - 0.031	0.624 + - 0.045
La-140	6.54 + - 0.29	7.39 + - 0.30	3.35 + - 0.16
Sm-153	0.685 + - 0.045	1.282 + - 0.068	0.464 + - 0.027
Yb-175	0.328 + - 0.069	0.619 + - 0.051	0.366 + - 0.046
Lu-177	< 0.045	0.113 + - 0.016	0.0498 + - 0.0092
W -187	< 0.80	< 0.49	< 0.35
Au-198	< 0.0056	0.1226 + - 0.0076	< 0.0028
Sc- 46	0.871 + - 0.036	1.591 + - 0.062	0.687 + - 0.027
Cr- 51	15.29 + - 0.99	7.52 + - 0.63	5.32 + - 0.46
Fe- 59	2450 + - 120	4550 + - 190	500 + - 36
Co- 60	0.835 + - 0.075	1.642 + - 0.099	0.333 + - 0.041
Zn- 65	< 2.8	18.3 + - 3.4	30.2 + - 3.6
Se- 75	< 2.3	< 0.60	< 1.06
Rb- 86	< 5.0	11.0 + - 2.5	< 3.0
Zr- 95	94 + - 24	< 37	62 + - 13
Ag-110	< 0.71	< 0.64	< 0.46
Cs-134	0.458 + - 0.078	0.533 + - 0.094	0.269 + - 0.047
Ba-131	3230 + - 130	784 + - 44	462 + - 29
Ce-141	10.97 + - 0.57	10.52 + - 0.58	6.40 + - 0.33
Nd-147	< 8.5	< 4.5	< 3.6
Eu-152	0.161 + - 0.028	0.305 + - 0.031	0.101 + - 0.020
Tb-160	< 0.117	< 0.16	< 0.047
Hf-181	2.19 + - 0.10	1.236 + - 0.069	2.073 + - 0.087
Ta-182	0.133 + - 0.038	< 0.160	< 0.141
Hg-203	< 0.36	< 0.26	< 0.21
Th-233	1.390 + - 0.079	1.873 + - 0.086	1.011 + - 0.053

	6200390	6200400	6200410
Na- 24	487 + 25	1403 + 52	156 + 12
Mg- 27	6720 + 300	2860 + 360	< 480
Al- 28	23470 ∓ 960	22220 ∓ 930	11610 + 570
Cl- 38	< 30	< 24	18.2 + 5.7
Ca- 49	37300 + 2200	10600 + 1200	< 260
Ti- 51	930 ∓ 120	950 ∓ 110	442 + 53
V - 52	178.0 ∓ 7.3	159.9 ∓ 6.7	22.7 + 1.7
Mn- 56	304 + 11	122.5 + 4.4	83.9 + 3.0
Cu- 66	< 120	280 + 66	< 61
Sr- 87	< 160	< 100	< 80
In-116	< 0.085	< 0.059	< 0.043
I -128	< 10.7	< 6.6	< 5.3
Ba-139	191 + 32	250 + 23	146 + 16
Dy-165	1.43 + 0.20	1.19 + 0.13	0.615 + 0.075
U -235	1.740 ∓ 0.049	2.056 ∓ 0.058	3.320 + 0.093
K - 42	12190 + 820	14890 + 920	6700 + 480
Ga- 72	< 4.3	< 3.9	< 2.3
As- 76	1.17 + 0.17	1.43 + 0.20	3.91 + 0.32
Br- 82	< 0.54	< 0.46	0.344 + 0.091
Mo- 99	< 4.0	< 2.8	1.55 + 0.28
Sb-122	0.250 + 0.057	0.269 + 0.047	0.256 + 0.030
La-140	13.60 ∓ 0.53	7.48 ∓ 0.32	6.60 + 0.28
Sm-153	1.744 + 0.085	1.192 + 0.058	0.645 + 0.042
Yb-175	0.801 + 0.075	0.694 + 0.070	0.546 + 0.050
Lu-177	0.115 + 0.019	0.090 + 0.018	0.100 + 0.021
W -187	< 0.70	< 0.70	< 0.45
Au-198	< 0.0048	0.1166 + 0.0075	< 0.0028
Sc- 46	2.88 + 0.11	1.789 + 0.070	1.060 + 0.042
Cr- 51	15.0 + 1.1	16.7 + 1.0	7.96 + 0.53
Fe- 59	6500 + 270	2560 + 120	1678 + 82
Co- 60	4.26 + 0.21	1.233 + 0.091	1.79 + 0.10
Zn- 65	36.5 + 5.0	14.5 + 3.3	41.8 + 4.6
Se- 75	< 1.25	< 0.70	< 1.1
Rb- 86	44.1 + 4.7	47.8 + 3.9	17.4 + 2.2
Zr- 95	157 ∓ 48	111 ∓ 22	52 + 10
Ag-110	< 1.18	< 0.72	< 0.46
Cs-134	1.93 + 0.16	1.38 + 0.12	0.633 + 0.077
Ba-131	170 + 28	277 + 28	107 + 13
Ce-141	25.7 + 1.1	14.71 + 0.71	12.39 + 0.53
Nd-147	< 10.9	< 5.2	< 4.3
Eu-152	0.437 + 0.048	0.308 + 0.036	0.157 + 0.024
Tb-160	0.204 + 0.045	< 0.12	< 0.11
Hf-181	2.42 + 0.12	3.63 + 0.15	2.65 + 0.11
Ta-182	< 0.29	0.294 + 0.055	< 0.174
Hg-203	< 0.47	< 0.30	< 0.25
Th-233	3.05 + 0.13	2.67 + 0.11	3.10 + 0.11

	6200420	6200430	6200440
Na- 24	147 ± 13	140 ± 11	367 ± 20
Mg- 27	1770 ± 300	720 ± 170	3620 ± 350
Al- 28	7960 ± 500	7910 ± 440	13780 ± 650
Cl- 38	479 ± 36	30.8 ± 6.8	65.7 ± 9.5
Ca- 49	63000 ± 3400	11900 ± 1100	1960 ± 420
Ti- 51	650 ± 150	528 ± 68	620 ± 62
V - 52	14.8 ± 1.8	15.3 ± 1.4	29.5 ± 2.0
Mn- 56	384 ± 13	91.9 ± 3.3	36.7 ± 1.4
Cu- 66	< 120	< 50	< 63
Sr- 87	< 180	< 71	< 66
In-116	< 0.082	< 0.035	< 0.041
I -128	< 12	< 4.6	< 4.3
Ba-139	< 80	549 ± 34	< 30
Dy-165	0.90 ± 0.18	0.571 ± 0.071	0.794 ± 0.085
U -235	0.721 ± 0.020	0.633 ± 0.018	0.978 ± 0.027
K - 42	1440 ± 230	3880 ± 340	4240 ± 390
Ga- 72	< 2.8	< 1.8	< 2.9
As- 76	1.48 ± 0.16	1.55 ± 0.16	1.55 ± 0.17
Br- 82	0.74 ± 0.12	0.286 ± 0.090	0.76 ± 0.15
Mo- 99	< 2.9	< 1.8	< 2.2
Sb-122	0.181 ± 0.036	0.139 ± 0.025	0.206 ± 0.035
La-140	4.82 ± 0.23	4.80 ± 0.22	5.99 ± 0.26
Sm-153	1.001 ± 0.049	0.650 ± 0.032	0.906 ± 0.046
Yb-175	0.548 ± 0.045	0.348 ± 0.033	0.711 ± 0.052
Lu-177	0.0645 ± 0.0092	0.067 ± 0.011	0.128 ± 0.011
W -187	< 0.46	< 0.34	< 0.52
Au-198	< 0.0031	< 0.0020	< 0.0031
Sc- 46	0.818 ± 0.034	0.911 ± 0.036	1.078 ± 0.043
Cr- 51	9.77 ± 0.74	6.61 ± 0.54	16.55 ± 0.96
Fe- 59	3030 ± 140	1325 ± 70	1609 ± 82
Co- 60	0.721 ± 0.073	0.732 ± 0.063	1.341 ± 0.087
Zn- 65	10.0 ± 3.3	7.6 ± 2.4	50.2 ± 5.6
Se- 75	< 1.3	< 1.2	< 1.6
Rb- 86	7.2 ± 2.0	10.7 ± 1.7	15.4 ± 2.0
Zr- 95	85 ± 21	67 ± 20	195 ± 28
Ag-110	< 0.56	< 0.38	< 0.49
Cs-134	0.621 ± 0.090	0.443 ± 0.067	0.840 ± 0.088
Ba-131	< 97	526 ± 33	108 ± 21
Ce-141	9.42 ± 0.51	8.56 ± 0.45	11.43 ± 0.55
Nd-147	< 7.9	< 3.9	< 5.1
Eu-152	0.242 ± 0.034	0.185 ± 0.026	0.202 ± 0.027
Tb-160	0.116 ± 0.029	< 0.100	0.187 ± 0.052
Hf-181	2.44 ± 0.11	1.962 ± 0.088	4.67 ± 0.17
Ta-182	< 0.232	< 0.133	0.380 ± 0.087
Hg-203	< 0.32	< 0.21	< 0.28
Th-233	1.125 ± 0.069	1.209 ± 0.064	1.857 ± 0.082

	6200450	6200460	6200470
Na- 24	284 + 17	209 + 16	1620 + 57
Mg- 27	800 + 180	< 880	4360 + 480
Al- 28	13170 + 630	9090 + 510	14710 + 680
Cl- 38	< 22	< 19	1680 + 100
Ca- 49	15400 + 1400	< 290	16700 + 1500
Ti- 51	500 + 110	< 300	670 + 100
V - 52	26.5 + 2.0	5.2 + 1.3	14.2 + 1.6
Mn- 56	117.4 + 4.2	364 + 13	223.2 + 7.8
Cu- 66	< 79	< 88	< 120
Sr- 87	< 100	< 140	< 140
In-116	< 0.054	< 0.063	< 0.077
I -128	< 6.9	< 9.4	< 9.1
Ba-139	184 + 25	149 + 25	155 + 24
Dy-165	0.67 + 0.11	< 0.38	0.99 + 0.12
U -235	0.689 + 0.019	0.2780 + 0.0078	2.469 + 0.069
K - 42	8210 + 630	7100 + 540	5900 + 490
Ga- 72	< 3.1	< 2.1	< 4.8
As- 76	1.08 + 0.14	1.86 + 0.19	1.84 + 0.20
Br- 82	< 0.39	< 0.26	2.47 + 0.25
Mo- 99	< 3.0	< 1.6	< 3.0
Sb-122	0.137 + 0.037	0.356 + 0.034	0.249 + 0.036
La-140	5.34 + 0.25	3.30 + 0.17	6.64 + 0.28
Sm-153	0.654 + 0.035	0.419 + 0.022	1.164 + 0.069
Yb-175	0.692 + 0.064	0.273 + 0.037	0.882 + 0.078
Lu-177	0.067 + 0.014	0.0514 + 0.0090	0.156 + 0.019
W -187	< 0.50	< 0.36	< 0.70
Au-198	< 0.0034	0.0309 + 0.0025	0.0504 + 0.0037
Sc- 46	1.007 + 0.041	0.831 + 0.033	1.631 + 0.064
Cr- 51	7.15 + 0.74	5.06 + 0.51	14.51 + 0.87
Fe- 59	2480 + 120	2240 + 110	2800 + 120
Co- 60	1.440 + 0.099	1.149 + 0.082	3.44 + 0.17
Zn- 65	< 1.6	5.3 + 2.4	32.6 + 4.0
Se- 75	< 0.89	< 1.3	< 1.7
Rb- 86	23.0 + 3.2	19.8 + 2.3	16.3 + 2.2
Zr- 95	< 70	83 + 19	240 + 31
Ag-110	< 0.76	< 0.50	< 0.55
Cs-134	0.91 + 0.11	0.690 + 0.077	0.520 + 0.076
Ba-131	209 + 26	146 + 17	152 + 20
Ce-141	9.50 + 0.54	11.32 + 0.55	12.52 + 0.54
Nd-147	< 8.0	< 3.9	< 4.9
Eu-152	0.224 + 0.032	0.127 + 0.024	0.251 + 0.026
Tb-160	< 0.10	< 0.073	< 0.13
Hf-181	2.12 + 0.10	1.967 + 0.089	5.49 + 0.19
Ta-182	< 0.247	< 0.153	0.177 + 0.043
Hg-203	< 0.34	< 0.21	< 0.30
Th-233	1.501 + 0.086	1.105 + 0.061	1.936 + 0.083

	6200480	6200490	6200500
Na- 24	415 ± 21	3270 ± 110	116 ± 12
Mg- 27	1290 ± 220	< 1500	6200 ± 530
Al- 28	23310 ± 930	14520 ± 770	8940 ± 520
Cl- 38	< 15	167 ± 30	36.2 ± 9.7
Ca- 49	< 260	97900 ± 4800	14300 ± 1300
Ti- 51	596 ± 66	< 500	< 350
V - 52	17.1 ± 1.5	589 ± 21	71.0 ± 3.8
Mn- 56	29.4 ± 1.1	744 ± 26	405 ± 14
Cu- 66	< 70	< 190	< 110
Sr- 87	< 69	< 230	< 170
In-116	< 0.046	< 0.121	< 0.079
I -128	< 4.3	< 15	< 11
Ba-139	267 ± 23	351 ± 43	< 69
Dy-165	1.01 ± 0.13	1.36 ± 0.36	0.62 ± 0.10
U -235	0.551 ± 0.015	100.5 ± 2.8	4.53 ± 0.13
K - 42	24800 ± 1400	6750 ± 550	3690 ± 350
Ga- 72	< 3.7	< 5.6	< 2.6
As- 76	1.70 ± 0.19	10.20 ± 0.81	5.30 ± 0.43
Br- 82	< 0.33	0.61 ± 0.15	< 0.32
Mo- 99	< 3.4	19.87 ± 0.74	4.21 ± 0.30
Sb-122	1.829 ± 0.099	< 0.14	0.461 ± 0.040
La-140	5.18 ± 0.24	7.42 ± 0.30	5.28 ± 0.24
Sm-153	0.865 ± 0.042	< 0.85	0.802 ± 0.055
Yb-175	0.781 ± 0.063	0.68 ± 0.10	0.603 ± 0.051
Lu-177	0.105 ± 0.013	< 0.093	0.085 ± 0.039
W -187	6.94 ± 0.59	< 0.83	< 0.40
Au-198	0.0360 ± 0.0030	< 0.0055	0.0067 ± 0.0011
Sc- 46	0.786 ± 0.032	1.417 ± 0.057	1.536 ± 0.060
Cr- 51	9.77 ± 0.85	10.79 ± 0.76	10.01 ± 0.69
Fe- 59	3490 ± 160	1637 ± 82	4780 ± 200
Co- 60	1.002 ± 0.083	1.230 ± 0.092	2.86 ± 0.14
Zn- 65	17.7 ± 3.4	8.4 ± 2.6	45.9 ± 5.1
Se- 75	< 1.5	1.44 ± 0.34	< 1.2
Rb- 86	64.9 ± 5.1	11.7 ± 1.5	10.2 ± 2.6
Zr- 95	< 87	115.5 ± 9.7	46.7 ± 8.6
Ag-110	< 0.71	< 0.52	< 0.56
Cs-134	1.32 ± 0.12	1.16 ± 0.11	0.462 ± 0.070
Ba-131	226 ± 25	355 ± 16	73 ± 11
Ce-141	6.42 ± 0.40	17.61 ± 0.67	10.40 ± 0.46
Nd-147	< 8.5	< 5.8	< 4.6
Eu-152	0.276 ± 0.038	0.205 ± 0.030	0.190 ± 0.028
Tb-160	0.166 ± 0.044	< 0.075	0.254 ± 0.065
Hf-181	4.07 ± 0.16	4.98 ± 0.18	2.62 ± 0.10
Ta-182	0.273 ± 0.080	0.220 ± 0.054	< 0.188
Hg-203	< 0.36	0.76 ± 0.30	< 0.28
Th-233	2.32 ± 0.11	1.710 ± 0.084	1.735 ± 0.078

	6200510	6200530	6200550
Na- 24	574 + - 26	2920 + - 93	17400 + - 500
Mg- 27	7760 + - 580	< 850	< 1700
Al- 28	13100 + - 630	14830 + - 680	21690 + - 950
Cl- 38	633 + - 43	61 + - 17	< 69
Ca- 49	8520 + - 930	14500 + - 1300	3160 + - 660
Ti- 51	684 + - 81	800 + - 77	< 420
V - 52	26.5 + - 2.0	108.1 + - 4.9	17.1 + - 2.1
Mn- 56	100.7 + - 3.6	68.8 + - 2.5	427 + - 15
Cu- 66	< 86	< 110	< 210
Sr- 87	< 110	87 + - 29	< 200
In-116	< 0.060	< 0.062	0.33 + - 0.10
I -128	< 6.8	< 6.2	< 13
Ba-139	257 + - 23	4030 + - 210	< 81
Dy-165	0.61 + - 0.14	0.894 + - 0.096	2.61 + - 0.25
U -235	1.959 + - 0.055	2.510 + - 0.070	0.957 + - 0.027
K - 42	11270 + - 810	13250 + - 870	< 1700
Ga- 72	< 4.3	< 6.5	< 12.4
As- 76	7.42 + - 0.60	4.42 + - 0.38	1.85 + - 0.34
Br- 82	1.44 + - 0.20	< 0.68	< 1.27
Mo- 99	< 3.6	< 3.7	< 6.3
Sb-122	0.207 + - 0.042	0.544 + - 0.060	0.49 + - 0.10
La-140	6.30 + - 0.28	8.19 + - 0.34	15.88 + - 0.62
Sm-153	0.927 + - 0.049	1.306 + - 0.071	2.39 + - 0.11
Yb-175	0.711 + - 0.074	0.791 + - 0.074	1.22 + - 0.13
Lu-177	0.087 + - 0.019	0.120 + - 0.027	0.175 + - 0.026
W -187	< 0.58	< 1.01	< 1.60
Au-198	< 0.0043	0.0174 + - 0.0022	< 0.011
Sc- 46	1.071 + - 0.043	1.513 + - 0.059	2.128 + - 0.083
Cr- 51	11.74 + - 0.86	10.22 + - 0.68	25.7 + - 1.4
Fe- 59	3080 + - 140	1233 + - 65	6400 + - 260
Co- 60	2.08 + - 0.13	5.20 + - 0.23	2.79 + - 0.14
Zn- 65	< 2.8	173 + - 16	15.5 + - 3.5
Se- 75	6.9 + - 1.2	< 1.6	< 1.1
Rb- 86	28.6 + - 3.4	36.6 + - 3.1	< 4.9
Zr- 95	116 + - 25	114 + - 20	< 60
Ag-110	< 0.80	< 0.72	< 0.76
Cs-134	0.542 + - 0.082	0.779 + - 0.086	< 0.078
Ba-131	320 + - 32	4050 + - 150	100 + - 19
Ce-141	12.30 + - 0.63	14.33 + - 0.63	29.5 + - 1.2
Nd-147	< 9.0	< 5.7	< 5.5
Eu-152	0.195 + - 0.033	0.304 + - 0.032	0.724 + - 0.053
Tb-160	< 0.12	0.195 + - 0.048	0.399 + - 0.051
Hf-181	3.95 + - 0.16	3.75 + - 0.14	1.919 + - 0.090
Ta-182	< 0.244	0.154 + - 0.040	0.190 + - 0.044
Hg-203	< 0.33	< 0.32	< 0.30
Th-233	1.939 + - 0.097	2.285 + - 0.096	3.64 + - 0.14

	6200560	6200570	6200590
Na- 24	327 + - 21	110 + - 11	< 37
Mg- 27	16970 + - 980	1610 + - 260	< 1500
Al- 28	9430 + - 560	7530 + - 440	3840 + - 450
Cl- 38	93 + - 12	22.0 + - 7.3	< 51
Ca- 49	33400 + - 2200	13000 + - 1200	27300 + - 2100
Ti- 51	< 360	340 + - 88	< 820
V - 52	15.7 + - 1.9	73.5 + - 3.7	< 6.5
Mn- 56	400 + - 14	96.5 + - 3.5	1197 + - 41
Cu- 66	< 110	< 70	< 200
Sr- 87	< 180	< 94	< 300
In-116	< 0.082	< 0.048	< 0.138
I -128	< 12	< 6.2	< 20
Ba-139	168 + - 21	62 + - 14	< 120
Dy-165	0.86 + - 0.12	< 0.41	0.93 + - 0.23
U -235	0.484 + - 0.014	0.590 + - 0.017	0.402 + - 0.011
K - 42	9440 + - 700	3590 + - 380	1250 + - 210
Ga- 72	< 3.1	< 2.7	< 2.4
As- 76	4.90 + - 0.41	1.75 + - 0.19	1.72 + - 0.17
Br- 82	0.65 + - 0.11	< 0.29	0.297 + - 0.067
Mo- 99	< 2.1	< 2.5	< 1.8
Sb-122	0.196 + - 0.034	0.162 + - 0.033	0.181 + - 0.024
La-140	4.55 + - 0.21	3.65 + - 0.19	6.88 + - 0.30
Sm-153	0.957 + - 0.048	0.465 + - 0.027	0.835 + - 0.041
Yb-175	0.453 + - 0.044	0.443 + - 0.049	0.653 + - 0.050
Lu-177	0.0769 + - 0.0087	0.062 + - 0.011	0.0955 + - 0.0081
W -187	< 0.41	< 0.42	< 0.34
Au-198	< 0.0030	< 0.0026	0.0176 + - 0.0016
Sc- 46	0.835 + - 0.033	0.631 + - 0.026	0.516 + - 0.021
Cr- 51	7.16 + - 0.54	6.52 + - 0.60	4.86 + - 0.41
Fe- 59	2140 + - 100	954 + - 62	1150 + - 60
Co- 60	2.25 + - 0.12	0.809 + - 0.074	1.040 + - 0.069
Zn- 65	25.2 + - 3.8	< 5.1	34.0 + - 3.9
Se- 75	< 1.2	< 0.79	< 0.37
Rb- 86	20.4 + - 2.4	18.5 + - 3.0	6.1 + - 1.7
Zr- 95	51 + - 14	< 57	< 41
Ag-110	< 0.59	< 0.62	< 0.44
Cs-134	0.659 + - 0.080	0.665 + - 0.088	0.276 + - 0.047
Ba-131	224 + - 24	< 74	57 + - 12
Ce-141	9.82 + - 0.45	7.84 + - 0.50	9.52 + - 0.45
Nd-147	< 4.3	< 6.8	< 3.5
Eu-152	0.220 + - 0.028	0.167 + - 0.031	0.190 + - 0.023
Tb-160	0.153 + - 0.030	< 0.051	0.134 + - 0.023
Hf-181	2.167 + - 0.093	1.370 + - 0.077	0.889 + - 0.049
Ta-182	< 0.175	< 0.229	< 0.149
Hg-203	< 0.25	< 0.28	< 0.19
Th-233	1.262 + - 0.063	1.263 + - 0.076	1.076 + - 0.053

	6200600	6200610	6200620
Na- 24	504 + 27	532 + 28	835 + 37
Mg- 27	16100 + 970	< 910	1870 + 300
Al- 28	8350 + 530	11980 + - 650	12040 ∓ 630
Cl- 38	130 + 19	174 + - 20	< 40
Ca- 49	27000 + - 2000	67300 + - 3600	57000 + 3200
Ti- 51	< 450	< 360	< 410
V - 52	23.0 + 2.3	49.5 + - 3.1	15.3 + - 2.0
Mn- 56	518 ∓ - 18	471 + - 16	515 + - 18
Cu- 66	< 140	< 110	< 130
Sr- 87	< 210	233 + 67	< 200
In-116	< 0.097	< 0.081	< 0.096
I -128	< 14	< 11	< 13
Ba-139	< 95	10030 + - 510	< 80
Dy-165	1.13 + 0.29	0.81 + - 0.13	0.90 + - 0.13
U -235	0.363 ∓ - 0.010	1.119 + - 0.031	0.518 + - 0.015
K - 42	9170 + - 730	6550 + - 540	11260 + - 800
Ga- 72	< 4.2	< 3.4	< 4.3
As- 76	2.46 + 0.25	0.48 + - 0.10	0.75 + 0.12
Br- 82	1.33 + - 0.18	0.54 + - 0.18	< 0.43
Mo- 99	< 3.3	< 2.7	< 2.5
Sb-122	0.167 + - 0.040	< 0.085	0.191 + 0.043
La-140	5.94 + - 0.27	10.45 + - 0.42	7.01 ∓ 0.30
Sm-153	1.273 + - 0.062	1.167 + - 0.060	1.172 + - 0.056
Yb-175	0.511 + - 0.055	0.721 + - 0.082	0.774 + - 0.057
Lu-177	0.068 + - 0.014	0.066 + - 0.022	0.1157 + - 0.0098
W -187	< 0.58	< 0.50	< 0.56
Au-198	< 0.0039	0.0115 + - 0.0015	0.0105 + - 0.0014
Sc- 46	0.999 + - 0.041	1.246 + - 0.050	1.178 + - 0.047
Cr- 51	5.39 + - 0.67	11.27 + - 0.90	3.39 + - 0.62
Fe- 59	3170 + - 150	1540 + - 82	2410 + - 110
Co- 60	2.04 + - 0.12	0.778 + - 0.066	1.146 + - 0.079
Zn- 65	16.0 + - 3.5	6.8 + - 2.8	33.0 + - 4.1
Se- 75	< 0.93	< 1.8	< 1.4
Rb- 86	21.9 + - 3.2	21.2 + - 2.7	30.1 + 2.8
Zr- 95	< 74	< 39	135 + 21
Ag-110	< 0.78	< 0.59	< 0.63
Cs-134	0.70 + 0.10	0.606 + - 0.084	0.739 + - 0.081
Ba-131	182 + 27	10480 + - 370	180 + - 22
Ce-141	13.86 ∓ - 0.75	17.50 + - 0.75	14.99 + - 0.67
Nd-147	< 8.3	14.4 + - 4.2	< 4.8
Eu-152	0.392 + 0.042	0.323 + - 0.035	0.290 + - 0.032
Tb-160	0.183 + 0.040	0.157 + - 0.041	0.185 + - 0.035
Hf-181	1.305 + - 0.077	1.366 + - 0.078	3.79 + - 0.14
Ta-182	0.150 + 0.048	< 0.152	0.143 + 0.034
Hg-203	< 0.34	< 0.32	< 0.27
Th-233	1.331 + - 0.079	1.843 + - 0.088	1.810 + - 0.083

	6200630	6200640	6200650
Na- 24	4160 + - 130	328 + - 20	430 + - 22
Mg- 27	< 1200	15050 + - 870	< 620
Al- 28	10810 + - 580	17880 + - 800	17310 + - 760
Cl- 38	61 + - 6	77 + - 5	176 + - 7
Ca- 49	5220 + - 750	31700 + - 2200	1790 + - 440
Ti- 51	< 430	520 + - 120	< 210
V - 52	21.2 + - 2.3	35.1 + - 2.5	6.7 + - 1.2
Mn- 56	491 + - 17	315 + - 11	130.1 + - 4.7
Cu- 66	< 160	< 94	< 79
Sr- 87	< 210	< 140	< 100
In-116	< 0.101	< 0.066	< 0.056
I -128	< 13	< 9.1	< 6.7
Ba-139	493 + - 44	3380 + - 180	288 + - 22
Dy-165	< 0.81	1.78 + - 0.18	0.794 + - 0.096
U -235	0.760 + - 0.021	0.680 + - 0.019	0.2950 + - 0.0083
K - 42	3350 + - 450	15500 + - 1000	23400 + - 1400
Ga- 72	< 8.5	< 3.5	3.44 + - 0.92
As- 76	1.26 + - 0.19	2.34 + - 0.23	3.22 + - 0.29
Br- 82	< 0.83	< 0.31	< 0.49
Mo- 99	< 5.1	< 2.4	< 2.3
Sb-122	0.377 + - 0.084	0.206 + - 0.035	1.127 + - 0.066
La-140	4.58 + - 0.23	10.78 + - 0.43	6.40 + - 0.28
Sm-153	0.827 + - 0.040	1.472 + - 0.071	1.017 + - 0.051
Yb-175	0.571 + - 0.094	0.836 + - 0.060	0.374 + - 0.049
Lu-177	0.061 + - 0.014	0.120 + - 0.014	0.067 + - 0.013
W -187	< 1.25	< 0.59	2.05 + - 0.26
Au-198	< 0.0068	< 0.0032	0.0057 + - 0.0013
Sc- 46	0.812 + - 0.033	2.069 + - 0.081	0.520 + - 0.021
Cr- 51	7.34 + - 0.64	12.50 + - 0.90	2.84 + - 0.33
Fe- 59	3270 + - 150	5960 + - 240	1856 + - 89
Co- 60	2.38 + - 0.14	2.15 + - 0.13	1.179 + - 0.078
Zn- 65	< 3.4	< 4.8	30.6 + - 3.7
Se- 75	< 1.8	< 1.9	< 0.77
Rb- 86	9.7 + - 1.9	33.9 + - 3.5	56.4 + - 4.1
Zr- 95	< 64	< 68	< 43
Ag-110	< 0.69	< 0.59	< 0.49
Cs-134	< 0.18	1.12 + - 0.11	0.977 + - 0.085
Ba-131	504 + - 35	3630 + - 140	306 + - 24
Ce-141	9.96 + - 0.53	20.81 + - 0.98	12.29 + - 0.57
Nd-147	< 7.8	< 6.0	< 4.1
Eu-152	0.256 + - 0.034	0.415 + - 0.039	0.298 + - 0.032
Tb-160	0.120 + - 0.029	0.317 + - 0.057	0.124 + - 0.027
Hf-181	1.497 + - 0.081	3.60 + - 0.15	1.079 + - 0.060
Ta-182	< 0.227	< 0.190	< 0.169
Hg-203	< 0.30	< 0.33	< 0.22
Th-233	1.318 + - 0.072	2.76 + - 0.12	0.995 + - 0.055

	6200670	6200690	6200710
Na- 24	3320 + - 110	313 + - 18	496 + - 25
Mg- 27	1340 + - 320	1310 + - 240	9060 + - 650
Al- 28	11960 + - 610	10580 + - 530	19390 + - 850
Cl- 38	49 + - 11	180 + - 17	62 + - 10
Ca- 49	20300 + - 1600	5660 + - 760	45700 + - 2700
Ti- 51	431 + - 88	573 + - 87	890 + - 110
V - 52	74.7 + - 3.8	112.6 + - 5.0	22.8 + - 2.1
Mn- 56	132.4 + - 4.8	51.2 + - 1.9	451 + - 16
Cu- 66	< 100	< 73	< 130
Sr- 87	< 100	< 78	< 190
In-116	< 0.058	< 0.046	< 0.087
I -128	< 6.6	< 5.0	< 12
Ba-139	< 43	177 + - 19	396 + - 32
Dy-165	0.765 + - 0.099	0.64 + - 0.11	1.60 + - 0.17
U -235	1.301 + - 0.036	2.352 + - 0.066	5.74 + - 0.16
K - 42	3160 + - 470	9380 + - 770	16600 + - 1100
Ga- 72	< 6.0	< 3.7	< 4.9
As- 76	< 0.45	1.20 + - 0.15	1.90 + - 0.20
Br- 82	< 0.58	< 0.39	0.99 + - 0.19
Mo- 99	< 3.0	< 3.0	3.06 + - 0.42
Sb-122	< 0.12	0.190 + - 0.030	0.303 + - 0.050
La-140	5.54 + - 0.25	4.89 + - 0.23	9.99 + - 0.40
Sm-153	0.793 + - 0.040	0.529 + - 0.033	2.06 + - 0.11
Yb-175	0.560 + - 0.078	0.413 + - 0.050	0.996 + - 0.066
Lu-177	0.071 + - 0.016	0.080 + - 0.017	0.179 + - 0.030
W -187	< 0.74	< 0.52	< 0.74
Au-198	< 0.0048	< 0.0033	< 0.0038
Sc- 46	0.996 + - 0.040	0.825 + - 0.034	2.082 + - 0.081
Cr- 51	15.44 + - 0.96	7.01 + - 0.67	12.29 + - 0.82
Fe- 59	1432 + - 76	1110 + - 69	15580 + - 590
Co- 60	0.693 + - 0.061	1.205 + - 0.090	2.43 + - 0.13
Zn- 65	< 2.9	10.5 + - 3.3	40.8 + - 4.9
Se- 75	< 1.2	< 0.87	< 1.8
Rb- 86	13.6 + - 2.0	21.9 + - 3.1	48.3 + - 4.1
Zr- 95	100 + - 18	88 + - 17	156 + - 23
Ag-110	< 0.40	< 0.54	< 0.92
Cs-134	0.711 + - 0.088	0.635 + - 0.087	1.52 + - 0.12
Ba-131	46 + - 11	207 + - 27	422 + - 33
Ce-141	10.58 + - 0.53	7.82 + - 0.46	19.84 + - 0.79
Nd-147	< 4.8	< 8.8	< 7.1
Eu-152	0.224 + - 0.029	0.155 + - 0.028	0.543 + - 0.045
Tb-160	0.121 + - 0.037	< 0.118	0.212 + - 0.034
Hf-181	2.96 + - 0.12	2.61 + - 0.12	4.72 + - 0.17
Ta-182	0.162 + - 0.048	< 0.235	0.309 + - 0.085
Hg-203	< 0.24	< 0.32	< 0.38
Th-233	1.673 + - 0.080	1.323 + - 0.074	2.48 + - 0.10

	6200720	6200730	6200740
Na- 24	500 + - 24	383 + - 23	173 + - 15
Mg- 27	1410 + - 270	3340 + - 510	2040 + - 340
Al- 28	21420 + - 880	13620 + - 680	13410 + - 670
Cl- 38	243 + - 20	< 28	< 38
Ca- 49	2100 + - 400	49600 + - 3000	72400 + - 3800
Ti- 51	413 + - 68	850 + - 130	< 400
V - 52	10.3 + - 1.2	690 + - 24	82.8 + - 4.2
Mn- 56	35.5 + - 1.3	229.6 + - 8.0	532 + - 19
Cu- 66	< 74	< 130	< 130
Sr- 87	< 74	< 140	<< 200
In-116	< 0.048	< 0.079	<< 0.093
I -128	< 4.8	< 9.0	< 13
Ba-139	369 + - 28	< 57	1061 + - 64
Dy-165	0.68 + - 0.12	0.71 + - 0.14	1.09 ∓ - 0.14
U -235	0.468 + - 0.013	31.47 + - 0.83	6.71 + - 0.19
K - 42	23500 + - 1500	9530 + - 730	4990 + - 450
Ga- 72	< 4.8	< 3.6	< 3.8
As- 76	1.51 + - 0.21	10.50 + - 0.83	11.74 + - 0.90
Br- 82	< 0.35	< 0.36	0.313 + - 0.093
Mo- 99	< 3.4	6.24 + - 0.31	≷ 2.5
Sb-122	1.197 + - 0.078	0.237 ∓ - 0.042	0.653 + - 0.051
La-140	4.00 + - 0.21	6.17 + - 0.27	7.94 + - 0.33
Sm-153	0.620 + - 0.030	< 0.76	1.303 + - 0.083
Yb-175	0.456 + - 0.062	0.619 + - 0.064	0.675 ∓ - 0.051
Lu-177	0.094 + - 0.012	< 0.093	0.138 + - 0.039
W -187	3.91 + - 0.45	< 0.56	< 0.54
Au-198	0.0155 + - 0.0021	0.477 + - 0.028	< 0.0032
Sc- 46	1.005 ∓ - 0.041	1.222 ∓ - 0.049	1.255 + - 0.049
Cr- 51	8.16 + - 0.74	10.87 + - 0.80	9.84 + - 0.73
Fe- 59	2310 + - 120	2370 + - 110	5270 + - 210
Co- 60	0.886 + - 0.077	0.490 + - 0.054	11.83 + - 0.49
Zn- 65	< 0.90	211 + - 20	50.9 + - 5.6
Se- 75	< 0.97	< 0.83	< 1.1
Rb- 86	55.4 + - 4.7	22.6 + - 2.8	16.1 + - 2.6
Zr- 95	83 + - 27	198 + - 21	143 + - 21
Ag-110	< 0.77	< 0.49	< 0.57
Cs-134	1.23 + - 0.11	1.02 + - 0.10	0.755 + - 0.087
Ba-131	420 + - 43	153 + - 11	1137 + - 56
Ce-141	8.48 + - 0.50	14.55 + - 0.63	15.52 + - 0.65
Nd-147	< 9.8	< 6.1	< 5.9
Eu-152	0.225 + - 0.037	0.215 + - 0.029	0.338 + - 0.034
Tb-160	< 0.122	< 0.052	0.216 + - 0.045
Hf-181	2.40 + - 0.11	5.14 + - 0.18	2.38 + - 0.10
Ta-182	< 0.253	0.351 + - 0.090	0.150 + - 0.049
Hg-203	< 0.36	< 0.30	< 0.31
Th-233	1.194 + - 0.076	1.664 + - 0.088	1.908 + - 0.086

	6200750	6200760	6200770
Na- 24	69.7 + 8.9	215 + 16	150 + 13
Mg- 27	< 850	< 720	< 710
Al- 28	4260 + 350	14730 + 710	9780 + 540
Cl- 38	37 + 11	< 24	31.7 + 9.2
Ca- 49	10800 + 1100	42500 + 2700	46500 + 2600
Ti- 51	< 370	437 + 89	707 + 83
V - 52	< 3.7	105.2 + 4.9	54.3 + 3.1
Mn- 56	419 + 15	298 + 10	281.1 + 9.8
Cu- 66	< 110	< 93	< 96
Sr- 87	< 180	< 130	< 140
In-116	< 0.077	< 0.067	< 0.068
I -128	< 12	< 8.7	< 9.2
Ba-139	< 80	1349 + 77	397 + 29
Dy-165	< 0.70	0.91 + 0.13	0.96 + 0.11
U -235	0.382 + 0.011	1.831 + 0.051	1.535 + 0.043
K - 42	1980 + 330	7080 + 640	5660 + 530
Ga- 72	< 2.9	< 3.3	< 3.5
As- 76	1.32 + 0.17	1.60 + 0.18	0.95 + 0.13
Br- 82	< 0.29	< 0.43	< 0.35
Mo- 99	< 2.5	< 2.1	< 2.2
Sb-122	0.167 + 0.026	0.164 + 0.031	0.205 + 0.031
La-140	3.01 + 0.17	8.06 + 0.35	7.31 + 0.31
Sm-153	0.474 + 0.024	1.046 + 0.058	1.291 + 0.065
Yb-175	0.392 + 0.042	0.566 + 0.049	0.683 + 0.048
Lu-177	0.0594 + 0.0083	0.096 + 0.014	0.125 + 0.013
W -187	< 0.40	< 0.49	< 0.56
Au-198	0.0121 + 0.0015	< 0.0028	< 0.0028
Sc- 46	0.364 + 0.016	1.296 + 0.052	1.138 + 0.046
Cr- 51	4.82 + 0.52	25.7 + 1.4	15.23 + 0.90
Fe- 59	2340 + 110	1802 + 92	4740 + 190
Co- 60	0.755 + 0.070	1.132 + 0.083	1.600 + 0.094
Zn- 65	< 2.1	7.3 + 2.7	41.5 + 4.6
Se- 75	< 1.2	< 1.6	< 1.4
Rb- 86	7.2 + 1.8	20.9 + 2.6	14.7 + 2.1
Zr- 95	79 + 18	138 + 24	137 + 20
Ag-110	< 0.55	< 0.46	< 0.64
Cs-134	0.414 + 0.066	0.731 + 0.083	0.648 + 0.077
Ba-131	< 89	1394 + 67	499 + 36
Ce-141	4.97 + 0.34	12.57 + 0.60	14.63 + 0.63
Nd-147	< 7.7	< 5.9	< 5.5
Eu-152	0.122 + 0.025	0.278 + 0.034	0.300 + 0.032
Tb-160	0.133 + 0.042	0.117 + 0.034	0.196 + 0.036
Hf-181	2.62 + 0.12	3.29 + 0.13	3.86 + 0.14
Ta-182	< 0.225	< 0.162	0.219 + 0.042
Hg-203	< 0.29	< 0.28	< 0.28
Th-233	1.001 + 0.069	1.659 + 0.083	1.458 + 0.070

	6200780	6200790	6200800
Na- 24	362 + 20	4830 + 150	5060 + 150
Mg- 27	2790 + 310	5120 + 520	1870 + 320
Al- 28	5630 + 380	17440 + 780	11610 + 580
Cl- 38	60.8 + 10.0	< 35	50 + 15
Ca- 49	14800 + 1300	5200 + 770	3500 + 590
Ti- 51	< 320	513 + 78	535 + 74
V - 52	12.0 + - 1.6	14.9 + - 1.5	23.8 + - 1.8
Mn- 56	306 + - 11	131.9 + - 4.7	27.6 + - 1.1
Cu- 66	< 98	< 110	< 120
Sr- 87	< 150	< 110	< 90
In-116	< 0.069	< 0.063	< 0.056
I -128	< 10.1	< 7.1	< 5.7
Ba-139	782 + - 52	388 + - 29	477 + - 31
Dy-165	0.98 + - 0.16	0.78 + - 0.11	0.519 + - 0.078
U -235	2.762 + - 0.077	0.624 + - 0.017	0.663 + - 0.019
K - 42	870 + - 200	4330 + - 610	< 1400
Ga- 72	< 4.3	< 7.9	< 9.9
As- 76	0.91 + 0.14	0.75 + - 0.15	< 0.66
Br- 82	0.42 + 0.12	< 0.71	0.88 + 0.32
Mo- 99	< 3.2	< 3.4	< 4.0
Sb-122	0.164 + - 0.031	< 0.14	< 0.17
La-140	7.84 + - 0.34	6.83 + - 0.31	7.45 + - 0.33
Sm-153	0.775 + - 0.046	0.825 + - 0.039	0.699 + - 0.038
Yb-175	0.435 + - 0.050	0.532 + - 0.082	0.66 + - 0.11
Lu-177	0.079 + - 0.024	< 0.038	0.061 + - 0.019
W -187	< 0.62	< 0.94	< 1.12
Au-198	0.0108 + 0.0014	0.0169 + 0.0024	0.0597 + 0.0045
Sc- 46	0.674 + - 0.028	1.404 + - 0.056	0.964 + - 0.039
Cr- 51	7.02 + - 0.67	6.23 + - 0.58	9.96 + - 0.69
Fe- 59	4280 + - 180	3400 + - 150	3860 + - 160
Co- 60	1.79 + - 0.11	2.33 + - 0.13	1.287 + - 0.081
Zn- 65	13.9 + - 3.6	20.0 + - 3.7	26.1 + - 3.6
Se- 75	< 0.86	< 1.7	< 1.1
Rb- 86	< 6.3	16.5 + 2.6	< 4.7
Zr- 95	< 52	< 58	122 + - 24
Ag-110	< 0.68	< 0.50	< 0.59
Cs-134	0.333 + - 0.079	0.671 + - 0.079	0.243 + - 0.048
Ba-131	919 + - 53	382 + - 34	485 + - 33
Ce-141	12.49 + - 0.74	11.02 + - 0.58	12.83 + - 0.56
Nd-147	< 9.3	< 5.3	< 5.1
Eu-152	0.190 + 0.029	0.203 + 0.030	0.142 + 0.023
Tb-160	< 0.119	0.149 + 0.044	0.137 + 0.031
Hf-181	1.001 + 0.068	1.584 + 0.082	2.33 + 0.10
Ta-182	< 0.236	0.137 + 0.037	< 0.170
Hg-203	< 0.33	< 0.27	< 0.26
Th-233	1.332 + - 0.075	1.948 + - 0.090	2.088 + - 0.092

	6200820	6200840	6200850
Na- 24	500 + 25	4410 + 140	405 + 21
Mg- 27	16470 + 970	< 1100	2950 + 350
Al- 28	14310 + - 720	9810 + - 530	15090 + - 690
Cl- 38	675 + - 47	81 + - 17	27.3 + - 7.1
Ca- 49	26900 + 2000	7470 + - 900	< 220
Ti- 51	< 320	< 330	638 + - 75
V - 52	28.4 + - 2.4	84.5 + - 4.1	29.8 + - 2.1
Mn- 56	359 + - 13	241.8 + - 8.5	56.7 + - 2.1
Cu- 66	< 100	< 140	< 56
Sr- 87	< 150	< 160	< 66
In-116	< 0.073	< 0.084	< 0.040
I -128	< 10.1	< 10.4	< 4.4
Ba-139	1292 + 75	< 73	177 + 17
Dy-165	< 0.43	< 0.63	0.727 + 0.088
U -235	0.461 + - 0.013	4.65 + - 0.13	0.638 + - 0.018
K - 42	12290 + - 910	3220 + - 680	9110 + - 760
Ga- 72	< 4.0	< 10.4	< 3.9
As- 76	0.78 + 0.15	7.56 + 0.64	0.89 + 0.16
Br- 82	1.85 + 0.21	1.27 + 0.36	< 0.36
Mo- 99	< 2.2	3.91 + 0.88	< 2.1
Sb-122	0.155 + - 0.031	0.395 + - 0.075	0.224 + - 0.035
La-140	6.10 + - 0.28	5.26 + - 0.26	6.32 + - 0.29
Sm-153	0.910 + - 0.044	0.652 + - 0.047	0.732 + - 0.038
Yb-175	0.458 + - 0.047	0.44 + - 0.11	0.583 + - 0.047
Lu-177	0.0639 + - 0.0094	< 0.042	0.113 + - 0.012
W -187	< 0.44	< 1.19	< 0.59
Au-198	0.0039 + - 0.0014	< 0.0070	< 0.0028
Sc- 46	1.110 + - 0.044	1.167 + 0.047	1.324 + 0.053
Cr- 51	8.90 + - 0.68	< 1.4	12.75 + 0.89
Fe- 59	2400 + - 110	2600 + - 120	4220 + - 180
Co- 60	1.406 + - 0.094	5.33 + - 0.25	1.84 + - 0.11
Zn- 65	10.3 + - 2.8	< 2.5	16.4 + - 3.4
Se- 75	< 1.5	< 0.90	< 1.5
Rb- 86	26.3 + 2.9	< 6.8	31.0 + 3.2
Zr- 95	83 + 23	49 + 11	164 + - 32
Ag-110	< 0.59	< 0.81	< 0.49
Cs-134	0.99 + - 0.10	0.399 + - 0.093	1.07 + - 0.10
Ba-131	1229 + - 61	88 + - 19	194 + - 28
Ce-141	10.40 + - 0.51	10.98 + - 0.56	11.69 + - 0.65
Nd-147	< 5.7	< 10.1	< 6.0
Eu-152	0.237 + 0.029	0.126 + 0.024	0.237 + 0.031
Tb-160	0.129 + 0.029	< 0.130	< 0.095
Hf-181	1.974 + 0.095	0.983 + 0.071	4.09 + - 0.16
Ta-182	0.223 + 0.057	< 0.258	< 0.172
Hg-203	< 0.27	< 0.35	< 0.28
Th-233	1.718 + - 0.091	1.312 + - 0.077	2.075 + - 0.100

	6200860		6200870		6200880	
Na- 24	1260	+ - 45	644	+ - 28	241	+ - 15
Mg- 27	4000	+ - 370	2090	+ - 270	< 340	
Al- 28	9660	+ - 500	9660	+ - 510	10190	+ - 530
Cl- 38	30.0	+ - 9.3	337	+ - 26	44.6	+ - 9.6
Ca- 49	1500	+ - 350	< 230		< 270	
Ti- 51	399	+ - 74	271	+ - 65	580	+ - 110
V - 52	24.8	+ - 1.8	172.6	+ - 6.9	8.4	+ - 1.3
Mn- 56	67.8	+ - 2.5	6.50	+ - 0.32	240.6	+ - 8.4
Cu- 66	< 77		< 66		< 82	
Sr- 87	< 86		< 52		< 130	
In-116	< 0.048		< 0.036		< 0.060	
I -128	< 5.6		< 3.2		< 8.2	
Ba-139	2480	+ - 130	145	+ - 15	154	+ - 20
Dy-165	0.521	+ - 0.095	0.347	+ - 0.062	0.56	+ - 0.11
U -235	0.941	+ - 0.026	2.091	+ - 0.059	0.3530	+ - 0.0099
K - 42	800	+ - 210	4360	+ - 370	7560	+ - 530
Ga- 72	< 4.8		< 2.7		< 2.3	
As- 76	1.01	+ - 0.17	2.89	+ - 0.26	1.75	+ - 0.17
Br- 82	< 0.56		1.55	+ - 0.17	0.35	+ - 0.15
Mo- 99	< 4.0		< 1.9		< 1.9	
Sb-122	0.136	+ - 0.032	0.217	+ - 0.033	0.605	+ - 0.043
La-140	6.39	+ - 0.30	3.95	+ - 0.19	4.64	+ - 0.21
Sm-153	0.725	+ - 0.038	0.349	+ - 0.024	0.490	+ - 0.027
Yb-175	0.448	+ - 0.076	0.321	+ - 0.055	0.346	+ - 0.045
Lu-177	0.058	+ - 0.017	< 0.019		0.0623	+ - 0.0066
W -187	< 0.72		< 0.39		0.79	+ - 0.13
Au-198	< 0.0049		< 0.0029		0.0484	+ - 0.0033
Sc- 46	0.920	+ - 0.037	0.593	+ - 0.025	0.812	+ - 0.032
Cr- 51	6.24	+ - 0.55	3.32	+ - 0.45	5.99	+ - 0.58
Fe- 59	3760	+ - 160	2340	+ - 110	1660	+ - 83
Co- 60	1.656	+ - 0.096	1.273	+ - 0.093	1.402	+ - 0.088
Zn- 65	54.6	+ - 5.7	< 4.2		11.3	+ - 2.7
Se- 75	< 1.6		1.57	+ - 0.33	< 1.3	
Rb- 86	7.8	+ - 2.3	10.2	+ - 3.2	22.5	+ - 2.5
Zr- 95	< 57		< 61		91	+ - 22
Ag-110	< 0.60		< 0.62		< 0.49	
Cs-134	0.355	+ - 0.051	0.501	+ - 0.083	0.576	+ - 0.069
Ba-131	3020	+ - 120	165	+ - 25	114	+ - 22
Ce-141	13.64	+ - 0.59	7.20	+ - 0.50	9.03	+ - 0.46
Nd-147	< 5.5		< 7.9		< 4.2	
Eu-152	0.222	+ - 0.027	0.071	+ - 0.022	0.119	+ - 0.021
Tb-160	< 0.106		< 0.138		< 0.079	
Hf-181	1.171	+ - 0.064	0.877	+ - 0.065	1.818	+ - 0.084
Ta-182	< 0.174		< 0.224		< 0.147	
Hg-203	< 0.27		< 0.30		< 0.22	
Th-233	1.466	+ - 0.070	1.127	+ - 0.070	1.371	+ - 0.073

	6200900	6200910	6200920
Na- 24	206 + - 17	346 + - 20	433 + - 22
Mg- 27	1910 + - 300	2120 + - 330	9960 + - 650
Al- 28	8930 + - 540	10380 + - 560	16150 + - 730
Cl- 38	389 + - 31	< 30	85 + - 11
Ca- 49	60900 + - 3400	42200 + - 2600	17400 + - 1400
Ti- 51	< 320	400 + - 120	< 280
V - 52	15.5 + - 1.8	52.6 + - 2.9	16.2 + - 1.6
Mn- 56	384 + - 13	310 + - 11	215.0 + - 7.5
Cu- 66	< 99	< 100	< 94
Sr- 87	< 150	< 150	< 130
In-116	< 0.070	< 0.073	< 0.066
I -128	< 9.8	< 9.8	< 8.7
Ba-139	170 + - 29	3160 + - 170	294 + - 28
Dy-165	1.44 + - 0.17	< 0.42	0.81 + - 0.14
U -235	0.684 + - 0.019	1.268 + - 0.036	0.576 + - 0.016
K - 42	1800 + - 250	6280 + - 480	15870 + - 970
Ga- 72	< 2.1	< 2.7	4.3 + - 1.3
As- 76	1.59 + - 0.16	0.633 + - 0.089	2.09 + - 0.22
Br- 82	0.69 + - 0.12	< 0.32	0.39 + - 0.11
Mo- 99	< 1.8	< 2.2	< 3.2
Sb-122	0.183 + - 0.026	0.131 + - 0.025	0.169 + - 0.038
La-140	4.26 + - 0.20	5.78 + - 0.25	5.95 + - 0.27
Sm-153	1.152 + - 0.054	0.854 + - 0.055	< 0.017
Yb-175	0.568 + - 0.045	0.544 + - 0.049	0.505 + - 0.060
Lu-177	0.0773 + - 0.0096	< 0.045	< 0.025
W -187	< 0.37	< 0.44	< 0.66
Au-198	0.00399 + - 0.00097	0.0168 + - 0.0016	< 0.0037
Sc- 46	0.881 + - 0.036	0.909 + - 0.036	1.338 + - 0.054
Cr- 51	9.92 + - 0.80	12.89 + - 0.82	7.15 + - 0.76
Fe- 59	3190 + - 150	1238 + - 68	3900 + - 170
Co- 60	0.843 + - 0.078	0.772 + - 0.066	1.276 + - 0.093
Zn- 65	19.3 + - 4.3	6.2 + - 2.5	< 5.9
Se- 75	< 1.2	< 1.4	< 1.1
Rb- 86	< 6.1	17.6 + - 2.5	44.7 + - 4.7
Zr- 95	92 + - 20	< 46	< 80
Ag-110	< 0.60	< 0.50	< 0.85
Cs-134	0.485 + - 0.089	0.649 + - 0.077	0.92 + - 0.11
Ba-131	< 113	3390 + - 130	319 + - 37
Ce-141	10.25 + - 0.58	11.32 + - 0.52	9.27 + - 0.61
Nd-147	< 9.7	< 5.2	< 10.3
Eu-152	0.292 + - 0.035	0.241 + - 0.029	0.292 + - 0.039
Tb-160	0.177 + - 0.054	0.123 + - 0.032	< 0.136
Hf-181	2.62 + - 0.12	1.189 + - 0.068	2.09 + - 0.10
Ta-182	< 0.233	< 0.153	< 0.260
Hg-203	< 0.35	< 0.24	< 0.38
Th-233	1.309 + - 0.077	1.323 + - 0.070	1.503 + - 0.083

	6200950	6200960	6200970
Na- 24	1294 + 49	6280 + 190	581 + 27
Mg- 27	3540 + 500	< 1050	5050 + 440
Al- 28	19950 ∓ 860	28000 + 1100	18810 ∓ 830
Cl- 38	< 34	60.3 + 9.5	286 + 24
Ca- 49	22400 + 1800	1330 + 340	10500 + 1100
Ti- 51	< 320	1140 + 110	622 + 100
V - 52	490 + 18	227.5 + 8.9	18.8 + 1.8
Mn- 56	197.7 + 6.9	41.3 + 1.6	266.5 + 9.3
Cu- 66	< 150	< 130	< 110
Sr- 87	< 160	< 100	< 150
In-116	< 0.090	< 0.067	< 0.074
I -128	< 10.1	< 6.4	< 9.7
Ba-139	468 + 39	237 + 23	516 + 36
Dy-165	1.15 + 0.23	1.11 + 0.13	1.16 + 0.13
U -235	16.78 ∓ 0.47	2.688 + 0.075	4.24 + 0.12
K - 42	13620 + 930	18400 + 1100	14790 + 920
Ga- 72	< 5.5	< 7.7	< 4.0
As- 76	2.35 + 0.25	3.24 + 0.36	1.69 + 0.18
Br- 82	< 0.62	< 0.82	1.39 + 0.17
Mo- 99	4.03 + 0.27	< 4.4	< 2.7
Sb-122	< 0.13	0.190 + 0.055	0.301 + 0.036
La-140	6.80 + 0.30	8.65 + 0.36	8.05 + 0.34
Sm-153	0.94 + 0.17	1.071 + 0.059	1.189 + 0.071
Yb-175	0.630 ∓ 0.074	0.551 + 0.090	0.791 + 0.055
Lu-177	< 0.078	0.092 + 0.023	0.124 + 0.031
W -187	< 0.94	< 1.13	< 0.51
Au-198	< 0.0053	0.182 + 0.011	< 0.0038
Sc- 46	1.537 + 0.061	2.240 + 0.087	1.490 + 0.058
Cr- 51	10.59 + 0.85	12.74 + 0.92	11.17 + 0.76
Fe- 59	2360 + 120	1482 + 80	7340 + 290
Co- 60	1.61 + 0.11	6.79 + 0.30	1.536 + 0.095
Zn- 65	< 0.18	10.0 + 3.3	24.6 + 3.9
Se- 75	< 2.4	< 1.9	< 1.7
Rb- 86	42.1 + 4.2	55.5 + 4.4	44.5 + 3.8
Zr- 95	< 66	109 + 21	94 + 18
Ag-110	< 2.03	< 0.61	< 0.76
Cs-134	1.58 + 0.14	1.44 + 0.13	1.27 + 0.11
Ba-131	521 + 36	241 + 27	514 + 36
Ce-141	14.80 + 0.74	14.79 + 0.68	15.42 + 0.65
Nd-147	< 11.6	< 8.3	< 6.3
Eu-152	0.303 + 0.039	0.266 + 0.032	0.351 + 0.036
Tb-160	0.458 + 0.045	< 0.11	0.189 + 0.041
Hf-181	2.50 + 0.12	4.14 + 0.16	3.21 ∓ 0.13
Ta-182	0.205 + 0.050	0.369 + 0.072	0.175 + 0.061
ng-203	< 0.42	< 0.33	< 0.32
Th-233	1.99 + 0.11	3.11 + 0.13	2.115 + 0.093

	6200980	6200990	6201000
Na- 24	4420 + 140	193 + 13	373 + 22
Mg- 27	< 1300	1310 + 200	2310 + 390
Al- 28	9880 + - 560	8730 + 480	13820 + - 680
Cl- 38	153 + - 20	< 10.9	< 32
Ca- 49	36400 + - 2300	< 220	48200 + 2900
Ti- 51	< 450	244 + 47	< 320
V - 52	30.4 + - 2.6	16.5 ∓ 1.5	678 + - 24
Mn- 56	515 + - 18	62.2 + - 2.3	231.5 + - 8.1
Cu- 66	< 170	< 48	< 150
Sr- 87	< 220	< 64	< 150
In-116	< 0.107	< 0.025	< 0.089
I -128	< 14	< 4.2	< 9.9
Ba-139	609 + 54	105 + 12	138 + 18
Dy-165	< 0.84	0.416 + 0.067	0.70 + 0.12
U -235	3.161 + 0.089	0.3140 ∓ 0.0088	28.86 ∓ 0.81
K - 42	< 1100	5230 + - 460	8600 + - 630
Ga- 72	< 8.2	< 2.1	< 3.4
As- 76	1.95 + 0.23	0.59 + 0.10	8.14 + 0.63
Br- 82	0.72 + 0.18	< 0.25	0.255 + 0.074
Mo- 99	< 5.5	< 1.6	4.01 + 0.22
Sb-122	< 0.18	0.155 + 0.034	0.245 + 0.039
La-140	5.59 + - 0.26	4.19 ∓ 0.20	6.67 ∓ 0.29
Sm-153	1.080 + - 0.058	0.472 + - 0.022	< 1.05
Yb-175	0.53 + - 0.13	0.279 + - 0.041	0.543 + 0.047
Lu-177	< 0.085	0.0534 + - 0.0095	< 0.12
W -187	< 1.18	< 0.32	< 0.52
Au-198	0.0199 + 0.0029	< 0.0022	0.0132 + 0.0016
Sc- 46	0.797 ∓ - 0.033	0.685 + - 0.028	1.226 + - 0.049
Cr- 51	7.28 + - 0.63	4.26 + - 0.49	10.06 + - 0.71
Fe- 59	2720 + - 130	1717 + - 88	2450 + - 110
Co- 60	1.367 + - 0.094	0.993 + - 0.073	0.636 + - 0.057
Zn- 65	< 5.6	7.9 + - 2.6	241 + - 22
Se- 75	< 1.3	< 0.49	< 1.5
Rb- 86	13.4 + - 2.5	13.1 + 2.2	29.0 + 2.8
Zr- 95	65 + - 17	< 44	182 + - 18
Ag-110	< 0.53	< 0.46	< 0.68
Cs-134	0.184 + - 0.054	0.714 + - 0.079	1.097 + - 0.100
Ba-131	602 + - 40	113 + - 23	216 + - 14
Ce-141	10.94 + - 0.63	7.30 + - 0.43	15.07 + - 0.63
Nd-147	< 8.9	< 4.1	7.1 + 2.2
Eu-152	0.210 + 0.029	0.126 + 0.022	0.228 + 0.030
Tb-160	0.126 + 0.043	< 0.056	< 0.141
Hf-181	2.38 ∓ 0.11	0.940 + - 0.059	4.74 + 0.17
Ta-182	< 0.226	< 0.153	< 0.197
Hg-203	< 0.32	< 0.21	< 0.31
Th-233	1.301 + - 0.072	1.061 + - 0.062	1.742 + - 0.073

	6201010			6201020			6201030		
Na- 24	6540	+ -	200	179	+ -	13	359	+ -	19
Mg- 27	5700	+ -	620	460	+ -	100	<	380	
Al- 28	22790	+ -	960	3100	+ -	450	10590	+ -	550
Cl- 38	<	58		22.2	+ -	6.9	134	+ -	14
Ca- 49	37600	+ -	2400	<	200		<	310	
Ti- 51	710	+ -	110	437	+ -	58	656	+ -	98
V - 52	18.9	+ -	2.2	7.63	+ -	0.98	16.7	+ -	1.7
Mn- 56	280.6	+ -	9.8	57.2	+ -	2.1	253.3	+ -	8.9
Cu- 66	<	170		<	44		<	88	
Sr- 87	<	180		<	59		<	130	
In-116	<	0.100		<	0.031		<	0.062	
I -128	<	12		<	3.8		<	8.6	
Ba-139	1013	+ -	65	111	+ -	13	107	+ -	17
Dy-165	0.77	+ -	0.16	0.249	+ -	0.073	0.77	+ -	0.11
U -235	0.728	+ -	0.020	0.3300	+ -	0.0092	1.827	+ -	0.051
K - 42	6970	+ -	740	6020	+ -	480	3980	+ -	330
Ga- 72	<	11.0		<	2.1		<	3.0	
As- 76	<	0.86		6.05	+ -	0.48	3.92	+ -	0.33
Br- 82	<	1.12		<	0.23		<	0.33	
Mo- 99	<	6.9		<	1.5		<	2.1	
Sb-122	<	0.24		0.631	+ -	0.045	0.303	+ -	0.033
La-140	8.59	+ -	0.38	2.84	+ -	0.15	5.29	+ -	0.23
Sm-153	1.256	+ -	0.059	0.264	+ -	0.015	0.904	+ -	0.047
Yb-175	0.74	+ -	0.13	0.277	+ -	0.036	0.457	+ -	0.040
Lu-177	0.161	+ -	0.029	0.0452	+ -	0.0075	0.078	+ -	0.015
W -187	<	1.46		0.52	+ -	0.13	0.55	+ -	0.13
Au-198	0.0365	+ -	0.0045	<	0.0021		0.0164	+ -	0.0017
Sc- 46	1.857	+ -	0.074	0.632	+ -	0.026	0.811	+ -	0.032
Cr- 51	10.24	+ -	0.90	4.82	+ -	0.45	9.87	+ -	0.70
Fe- 59	5580	+ -	240	1853	+ -	93	2500	+ -	120
Co- 60	2.23	+ -	0.13	2.55	+ -	0.14	2.28	+ -	0.12
Zn- 65	15.9	+ -	4.0	18.7	+ -	3.4	38.3	+ -	4.3
Se- 75	<	1.14		<	1.2		<	1.2	
Rb- 86	17.6	+ -	4.2	18.8	+ -	2.9	16.4	+ -	2.6
Zr- 95	<	83		74	+ -	15	108	+ -	17
Ag-110	<	0.99		<	0.35		<	0.43	
Cs-134	1.26	+ -	0.14	0.642	+ -	0.071	0.399	+ -	0.062
Ba-131	1035	+ -	75	<	80		104	+ -	19
Ce-141	16.56	+ -	0.83	4.60	+ -	0.34	10.17	+ -	0.52
Nd-147	<	16		<	5.8		<	6.5	
Eu-152	0.373	+ -	0.043	0.095	+ -	0.018	0.236	+ -	0.027
Tb-160	<	0.21		<	0.083		0.093	+ -	0.023
Hf-181	2.06	+ -	0.11	2.34	+ -	0.10	3.41	+ -	0.13
Ta-182	0.225	+ -	0.053	<	0.148		0.215	+ -	0.043
Hg-203	<	0.45		<	0.22		<	0.26	
Th-233	2.34	+ -	0.12	1.066	+ -	0.064	1.418	+ -	0.069

	6201040	6201050	6201070
Na- 24	84.9 + - 9.6	114 + - 11	286 + - 17
Mg- 27	2810 + - 310	2620 + - 340	910 + - 260
Al- 28	6410 ∓ - 390	14220 ∓ - 670	16820 ∓ - 740
Cl- 38	< 18	< 19	36.1 + - 9.9
Ca- 49	8150 + - 900	24300 + - 1800	< 320
Ti- 51	< 220	466 ∓ - 69	620 + - 110
V - 52	115.3 + - 5.1	27.8 ∓ - 2.0	14.7 + - 1.7
Mn- 56	142.2 + - 5.0	153.1 + - 5.4	249.6 + - 8.7
Cu- 66	< 82	138 + - 37	< 99
Sr- 87	< 110	< 98	< 140
In-116	< 0.054	< 0.048	< < 0.068
I -128	< 7.0	< 6.5	< < 9.2
Ba-139	< 48	420 + - 32	173 + - 27
Dy-165	< 0.43	1.05 + - 0.11	0.65 + - 0.13
U -235	2.354 + - 0.066	0.933 ∓ - 0.026	0.602 + - 0.017
K - 42	2510 + - 320	3680 + - 350	12740 + - 890
Ga- 72	< 2.6	< 2.6	< 3.7
As- 76	1.99 + - 0.20	1.88 + - 0.19	7.15 + - 0.58
Br- 82	< 0.30	0.47 + - 0.22	< 0.42
Mo- 99	< 2.5	< 2.1	< 3.1
Sb-122	0.223 + - 0.033	0.272 + - 0.038	1.638 + - 0.092
La-140	3.39 ∓ - 0.18	10.18 ∓ - 0.41	3.16 ∓ - 0.17
Sm-153	0.490 + - 0.031	1.222 + - 0.059	0.478 + - 0.028
Yb-175	0.331 + - 0.038	0.574 + - 0.051	0.559 + - 0.061
Lu-177	0.070 + - 0.020	0.111 + - 0.013	0.092 + - 0.014
W -187	< 0.41	< 0.49	1.18 + - 0.20
Au-198	0.0358 + - 0.0028	< 0.0027	< 0.0036
Sc- 46	0.850 ∓ - 0.035	1.208 + - 0.048	1.454 + - 0.058
Cr- 51	5.84 + - 0.69	7.07 + - 0.63	11.16 + - 0.98
Fe- 59	2150 + - 110	2820 + - 130	3680 + - 170
Co- 60	1.391 + - 0.095	1.172 + - 0.084	2.60 + - 0.15
Zn- 65	5.5 + - 2.8	20.4 + - 3.7	19.1 + - 4.0
Se- 75	< 0.79	< 1.5	< 1.5
Rb- 86	< 5.9	15.2 + - 2.6	41.7 + - 5.1
Zr- 95	70 + - 18	< 47	158 + - 28
Ag-110	< 0.54	< 0.58	< 0.86
Cs-134	0.415 + - 0.079	0.622 + - 0.077	1.24 + - 0.12
Ba-131	< 117	463 + - 40	204 + - 42
Ce-141	6.02 + - 0.40	18.94 + - 0.81	9.04 + - 0.67
Nd-147	< 10.8	< 7.0	< 14
Eu-152	0.143 + - 0.033	0.309 + - 0.035	0.181 + - 0.033
Tb-160	< 0.114	0.268 + - 0.053	< 0.10
Hf-181	1.232 + - 0.075	1.838 + - 0.085	3.78 + - 0.16
Ta-182	< 0.214	< 0.174	< 0.262
Hg-203	< 0.32	< 0.27	< 0.41
Th-233	0.951 + - 0.068	2.49 + - 0.11	1.87 + - 0.10

	6201080	6201100	6201110
Na- 24	554 + 27	187 + 13	865 + - 36
Mg- 27	12140 + 750	740 + 200	6260 + - 540
Al- 28	14470 ∓ 690	11570 + 570	16070 + - 740
Cl- 38	614 + 43	26.0 + 7.2	135 + - 17
Ca- 49	20400 + ∓700	< 260	10400 + - 1100
Ti- 51	547 + 99	734 + 86	965 + - 98
V - 52	26.3 + - 2.0	25.5 ∓ 1.8	109.3 + - 5.0
Mn- 56	168.9 + - 5.9	91.3 + - 3.3	186.2 + - 6.5
Cu- 66	< 80	< 67	119 + - 40
Sr- 87	< 110	< 89	< 110
In-116	< 0.055	< 0.046	< 0.059
I -128	< 7.0	< 5.8	< 7.3
Ba-139	342 + 31	120 + 21	141 + - 18
Dy-165	0.89 + - 0.12	1.03 + 0.14	1.19 + - 0.13
U -235	1.638 + - 0.046	3.235 ∓ 0.091	1.837 + - 0.051
K - 42	11700 + - 800	7170 + - 600	11440 + - 840
Ga- 72	< 3.7	< 3.7	< 3.9
As- 76	2.69 + 0.26	7.03 + - 0.57	2.22 + - 0.23
Br- 82	12.9 + 1.0	< 0.41	< 0.41
Mo- 99	≷ 2.3	< 3.3	< 2.3
Sb-122	0.268 + 0.051	0.364 + 0.043	0.259 + - 0.037
La-140	5.96 ∓ 0.27	7.17 ∓ 0.32	5.71 + - 0.26
Sm-153	0.958 + - 0.049	1.428 + 0.083	0.977 + - 0.049
Yb-175	0.489 + - 0.056	0.897 ∓ 0.063	0.915 + - 0.067
Lu-177	0.054 + 0.018	0.183 + 0.020	0.149 + - 0.015
W -187	< 0.53	< 0.63	< 0.62
Au-198	< 0.0035	< 0.0035	< 0.0033
Sc- 46	1.072 + - 0.043	1.028 + - 0.042	1.343 + - 0.054
Cr- 51	9.91 + - 0.75	11.08 + - 0.95	24.7 + - 1.4
Fe- 59	3390 + - 150	2310 + - 120	2340 + - 110
Co- 60	1.324 + - 0.089	3.47 + - 0.18	1.84 + - 0.11
Zn- 65	5.9 + - 2.6	43.2 + - 5.7	13.5 + - 3.2
Se- 75	< 1.5	< 2.1	< 0.82
Rb- 86	22.6 + - 3.4	22.3 + - 4.2	36.3 + - 3.8
Zr- 95	75 + - 18	99 + - 19	195 + - 26
Ag-110	< 0.56	< 0.76	< 0.48
Cs-134	0.730 + - 0.083	0.517 + 0.087	1.057 + - 0.098
Ba-131	194 + - 28	< 142	178 + - 30
Ce-141	11.34 + - 0.62	12.47 + - 0.65	9.48 + - 0.53
Nd-147	< 7.1	< 13.6	< 8.0
Eu-152	0.217 + 0.028	0.397 + - 0.044	0.246 + - 0.032
Tb-160	< 0.074	< 0.19	0.214 + - 0.046
Hf-181	2.68 + 0.12	3.79 + - 0.16	6.68 + - 0.23
Ta-182	< 0.160	< 0.26	0.297 + - 0.058
Hg-203	< 0.27	< 0.39	< 0.31
Th-233	1.656 + - 0.084	1.94 + - 0.11	1.916 + - 0.094

	6201120	6201130	6201140
Na- 24	1393 + - 52	330 + - 20	2537 + - 84
Mg- 27	2530 + - 380	12890 + - 810	2390 + - 360
Al- 28	19820 + - 850	7650 + - 470	14370 + - 690
Cl- 38	< 29	161 + - 18	< 35
Ca- 49	17400 + - 1400	53700 + - 3000	36100 + - 2300
Ti- 51	810 + - 92	< 380	600 + - 120
V - 52	111.0 + - 5.0	97.0 + - 4.6	9.3 + - 1.5
Mn- 56	123.2 + - 4.4	416 + - 15	346 + - 12
Cu- 66	< 100	< 130	< 110
Sr- 87	< 110	< 190	< 150
In-116	< 0.066	< 0.087	< 0.071
I -128	< 7.4	< 12	< 9.5
Ba-139	251 + - 22	531 + - 46	1850 + - 100
Dy-165	0.96 + - 0.11	< 0.73	0.91 + - 0.12
U -235	1.218 + - 0.034	3.478 + - 0.097	8.32 + - 0.23
K - 42	14740 + - 970	5100 + - 510	8550 + - 700
Ga- 72	< 5.6	< 4.1	< 5.4
As- 76	0.97 + - 0.15	3.28 + - 0.29	10.05 + - 0.79
Br- 82	0.76 + - 0.19	0.80 + - 0.25	< 0.53
Mo- 99	< 2.9	< 3.3	< 2.9
Sb-122	0.317 + - 0.041	0.228 + - 0.034	0.572 + - 0.059
La-140	7.53 + - 0.32	5.93 + - 0.27	5.27 + - 0.24
Sm-153	1.143 + - 0.058	0.896 + - 0.053	0.997 + - 0.071
Yb-175	0.842 + - 0.074	0.612 + - 0.061	0.455 + - 0.073
Lu-177	0.152 + - 0.016	0.077 + - 0.028	< 0.116
W -187	< 0.86	< 0.63	< 0.66
Au-198	< 0.0044	< 0.0035	< 0.0044
Sc- 46	1.703 + - 0.066	0.834 + - 0.034	1.230 + - 0.049
Cr- 51	18.0 + - 1.1	6.44 + - 0.69	8.09 + - 0.68
Fe- 59	2021 + - 99	7900 + - 320	2060 + - 100
Co- 60	0.884 + - 0.069	3.01 + - 0.16	4.62 + - 0.21
Zn- 65	45.7 + - 5.2	23.9 + - 4.3	29.3 + - 4.2
Se- 75	< 1.3	< 1.7	< 1.5
Rb- 86	49.4 + - 4.4	< 8.3	27.2 + - 3.5
Zr- 95	131 + - 26	137 + - 25	137 + - 19
Ag-110	< 0.74	< 0.80	< 0.63
Cs-134	1.45 + - 0.11	0.308 + - 0.077	0.692 + - 0.078
Ba-131	260 + - 33	522 + - 49	1812 + - 85
Ce-141	12.94 + - 0.58	11.56 + - 0.62	11.03 + - 0.55
Nd-147	< 8.1	< 13.0	< 7.5
Eu-152	0.308 + - 0.036	0.223 + - 0.031	0.223 + - 0.028
Tb-160	0.155 + - 0.034	0.226 + - 0.065	0.139 + - 0.051
Hf-181	4.24 + - 0.16	3.35 + - 0.14	2.71 + - 0.11
Ta-182	< 0.206	< 0.27	< 0.173
Hg-203	< 0.33	< 0.39	< 0.28
Th-233	2.44 + - 0.11	1.63 + - 0.10	1.341 + - 0.076

	6201160	6201180	6201190
Na- 24	168 + - 14	923 + - 38	60.1 + - 6.9
Mg- 27	1280 + - 280	5820 + - 490	< 240
Al- 28	10240 + - 560	16420 + - 740	4030 + - 290
Cl- 38	< 30	129 + - 14	37.9 + - 6.1
Ca- 49	49200 + - 2900	9400 + - 1100	< 230
Ti- 51	< 320	1020 + - 100	153 + - 33
V - 52	33.2 + - 2.3	121.8 + - 5.4	< 0.95
Mn- 56	295 + - 10	205.5 + - 7.2	10.45 + - 0.47
Cu- 66	< 100	< 110	< 32
Sr- 87	< 160	< 130	< 37
In-116	< 0.073	< 0.071	< 0.021
I -128	< 10.2	< 8.6	< 2.4
Ba-139	< 72	246 + - 23	310 + - 23
Dy-165	0.84 + - 0.17	1.42 + - 0.15	0.341 + - 0.100
U -235	0.865 + - 0.024	2.351 + - 0.066	0.2400 + - 0.0067
K - 42	5820 + - 590	11540 + - 840	< 280
Ga- 72	< 4.0	< 4.9	< 2.5
As- 76	0.90 + - 0.15	3.16 + - 0.28	0.97 + - 0.13
Br- 82	< 0.41	0.82 + - 0.15	< 0.26
Mo- 99	< 3.2	0.609 + - 0.093	< 2.2
Sb-122	0.159 + - 0.036	0.310 + - 0.045	0.204 + - 0.029
La-140	7.93 + - 0.35	5.92 + - 0.27	2.24 + - 0.14
Sm-153	1.116 + - 0.058	0.949 + - 0.050	0.220 + - 0.013
Yb-175	0.455 + - 0.044	1.064 + - 0.071	0.219 + - 0.032
Lu-177	0.095 + - 0.015	0.194 + - 0.016	0.0405 + - 0.0072
W -187	< 0.53	< 0.60	< 0.33
Au-198	< 0.0034	< 0.0038	< 0.0022
Sc- 46	0.959 + - 0.039	1.485 + - 0.058	0.1457 + - 0.0079
Cr- 51	4.41 + - 0.72	39.5 + - 2.0	1.77 + - 0.31
Fe- 59	2700 + - 130	2520 + - 120	733 + - 55
Co- 60	1.224 + - 0.095	1.67 + - 0.10	0.102 + - 0.041
Zn- 65	9.6 + - 3.5	43.8 + - 4.9	< 1.7
Se- 75	< 0.90	1.25 + - 0.55	< 0.64
Rb- 86	18.3 + - 3.3	38.9 + - 3.9	< 4.7
Zr- 95	< 74	282 + - 35	< 42
Ag-110	< 0.73	< 0.66	< 0.43
Cs-134	0.640 + - 0.088	1.22 + - 0.10	0.152 + - 0.035
Ba-131	< 154	282 + - 32	316 + - 33
Ce-141	15.72 + - 0.75	12.22 + - 0.61	3.41 + - 0.31
Nd-147	< 12.5	< 8.5	< 9.3
Eu-152	0.305 + - 0.039	0.301 + - 0.032	< 0.065
Tb-160	0.165 + - 0.044	0.150 + - 0.036	0.110 + - 0.036
Hf-181	1.320 + - 0.084	8.04 + - 0.27	0.665 + - 0.051
Ta-182	< 0.246	0.286 + - 0.058	< 0.208
Hg-203	< 0.35	< 0.34	< 0.25
Th-233	1.264 + - 0.080	2.40 + - 0.11	0.466 + - 0.048

	6201200	6201210	6201220
Na- 24	629 + 30	2606 + 86	721 + 31
Mg- 27	5530 + 550	< 1100	2150 + 330
Al- 28	16980 ∓ 780	6130 + 450	3400 ∓ 480
Cl- 38	< 24	< 50	< 22
Ca- 49	23800 + 1900	97400 + 4700	5280 + 730
Ti- 51	660 + 100	1040 + 140	< 200
V - 52	26.9 + 2.1	22.1 + 2.0	480 + 17
Mn- 56	191.1 ∓ 6.7	492 + 17	39.4 + 1.5
Cu- 66	< 83	< 150	< 110
Sr- 87	< 110	< 190	< 92
In-116	< 0.057	< 0.097	< 0.062
I -128	< 7.5	< 13	< 6.0
Ba-139	510 + 35	2490 + 130	95 + 15
Dy-165	1.04 ∓ 0.13	1.08 + 0.14	< 0.41
U -235	0.708 + 0.020	0.781 + 0.022	6.17 + 0.17
K - 42	7310 + 630	3480 + 510	4320 + 500
Ga- 72	< 4.1	< 6.7	< 4.9
As- 76	2.20 + 0.25	< 0.47	1.69 + 0.21
Br- 82	< 0.33	< 0.60	< 0.46
Mo- 99	< 2.4	< 3.2	< 3.3
Sb-122	0.160 + 0.045	0.389 + 0.049	0.117 + 0.033
La-140	7.97 + 0.34	7.06 + 0.30	3.53 + 0.19
Sm-153	1.282 + 0.060	0.926 + 0.047	0.401 + 0.067
Yb-175	0.689 + 0.059	1.016 + 0.070	0.368 + 0.057
Lu-177	0.118 + 0.013	0.180 + 0.015	< 0.056
W -187	< 0.63	0.98 + 0.24	< 0.65
Au-198	< 0.0033	0.0161 + 0.0019	0.0132 + 0.0017
Sc- 46	1.575 + 0.063	0.972 + 0.039	0.643 + 0.027
Cr- 51	13.39 + 0.95	22.2 + 1.2	3.61 + 0.48
Fe- 59	4920 + 210	7200 + 280	1641 + 94
Co- 60	1.85 + 0.11	1.109 + 0.072	0.705 + 0.071
Zn- 65	< 4.1	28.1 + 3.5	< 0.087
Se- 75	< 1.8	< 1.6	< 1.7
Rb- 86	24.7 + 3.6	6.4 + 1.7	15.2 + 2.7
Zr- 95	149 + 34	219 + 28	68 + 15
Ag-110	< 0.53	< 0.47	< 1.11
Cs-134	1.36 + 0.12	< 0.073	0.556 + 0.085
Ba-131	543 + 46	2620 + 110	120 ∓ 21
Ce-141	13.74 ∓ 0.74	12.44 + 0.57	6.91 + 0.44
Nd-147	< 8.3	< 8.0	< 11.2
Eu-152	0.329 + 0.037	0.229 + 0.025	0.082 + 0.023
Tb-160	0.134 ∓ 0.032	0.116 + 0.032	< 0.116
Hf-181	3.92 + 0.16	6.32 + 0.21	1.022 + 0.072
Ta-182	< 0.188	0.171 + 0.047	< 0.231
Hg-203	< 0.33	< 0.31	< 0.32
Th-233	2.12 + 0.11	1.884 + 0.087	1.134 + 0.075

	6201230	6201260	6201270
Na- 24	4930 + - 150	666 + - 31	6910 + - 210
Mg- 27	1990 + - 460	3210 + - 410	6220 + - 500
Al- 28	16210 + - 790	14500 + - 710	20260 + - 870
Cl- 38	< 50	< 25	215 + - 20
Ca- 49	49100 + - 2900	35800 + - 2300	2290 + - 450
Ti- 51	< 410	405 + - 79	517 + - 86
V - 52	113.6 + - 5.5	107.0 + - 5.0	18.1 + - 1.6
Mn- 56	572 + - 20	197.0 + - 6.9	48.4 + - 1.8
Cu- 66	< 160	< 88	< 140
Sr- 87	< 190	< 120	< 110
In-116	< 0.100	< 0.060	< 0.071
I -128	< 13	< 7.5	< 7.2
Ba-139	< 79	205 + - 23	728 + - 45
Dy-165	1.05 + - 0.15	0.76 + - 0.12	0.715 + - 0.094
U -235	4.87 + - 0.14	0.868 + - 0.024	1.190 + - 0.033
K - 42	4400 + - 540	10090 + - 780	2380 + - 520
Ga- 72	< 7.8	< 4.1	< 11.2
As- 76	1.02 + - 0.17	0.55 + - 0.10	0.78 + - 0.26
Br- 82	< 0.70	< 0.38	< 0.94
Mo- 99	< 3.6	< 2.2	< 4.4
Sb-122	< 0.14	0.228 + - 0.036	< 0.19
La-140	7.57 + - 0.33	6.84 + - 0.30	5.89 + - 0.27
Sm-153	1.440 + - 0.076	0.881 + - 0.042	0.683 + - 0.041
Yb-175	0.627 + - 0.089	0.475 + - 0.055	0.57 + - 0.11
Lu-177	0.103 + - 0.035	0.074 + - 0.010	0.131 + - 0.024
W -187	< 0.94	< 0.61	< 1.21
Au-198	< 0.0056	0.0058 + - 0.0013	0.0349 + - 0.0034
Sc- 46	1.394 + - 0.056	1.206 + - 0.048	1.352 + - 0.054
Cr- 51	7.42 + - 0.68	7.51 + - 0.65	5.01 + - 0.63
Fe- 59	2460 + - 120	2790 + - 130	4820 + - 200
Co- 60	2.13 + - 0.12	1.84 + - 0.11	2.24 + - 0.12
Zn- 65	13.2 + - 3.2	7.1 + - 2.8	94.3 + - 9.1
Se- 75	< 1.5	< 0.59	< 0.78
Rb- 86	14.0 + - 2.6	26.7 + - 3.4	12.4 + - 2.6
Zr- 95	67 + - 15	78 + - 21	< 68
Ag-110	< 0.60	< 0.58	< 0.70
Cs-134	0.603 + - 0.075	0.961 + - 0.100	0.648 + - 0.098
Ba-131	< 108	171 + - 35	737 + - 50
Ce-141	16.15 + - 0.74	11.21 + - 0.61	11.70 + - 0.54
Nd-147	< 7.2	< 5.9	< 7.5
Eu-152	0.315 + - 0.035	0.202 + - 0.026	0.156 + - 0.025
Tb-160	< 0.15	< 0.138	< 0.090
Hf-181	2.43 + - 0.11	2.125 + - 0.100	1.790 + - 0.088
Ta-182	< 0.169	< 0.174	0.216 + - 0.047
Hg-203	< 0.28	< 0.27	< 0.31
Th-233	2.16 + - 0.10	1.642 + - 0.085	2.64 + - 0.11

	6201280	6201290	6201300
Na- 24	4880 + - 150	124 + - 12	1930 + - 66
Mg- 27	< 1100	3340 + - 370	1840 + - 350
Al- 28	6100 + - 400	16340 + - 750	16820 + - 770
Cl- 38	61 + - 11	< 22	< 36
Ca- 49	3330 + - 570	34100 + - 2300	31700 + - 2300
Ti- 51	< 340	< 250	1340 + - 110
V - 52	9.6 + - 1.7	27.3 + - 2.2	81.5 + - 4.0
Mn- 56	262.7 + - 9.2	222.2 + - 7.8	186.6 + - 6.5
Cu- 66	< 140	360 + - 67	< 120
Sr- 87	< 160	< 120	< 130
In-116	< 0.084	< 0.057	< 0.073
I -128	< 10.5	< 7.8	< 8.6
Ba-139	302 + - 36	508 + - 37	466 + - 34
Dy-165	< 0.63	1.25 + - 0.13	1.40 + - 0.14
U -235	0.398 + - 0.011	0.956 + - 0.027	1.437 + - 0.040
K - 42	< 1400	5130 + - 550	13180 + - 990
Ga- 72	< 10.5	< 3.6	< 7.0
As- 76	1.72 + - 0.27	1.31 + - 0.17	1.05 + - 0.18
Br- 82	< 0.89	0.74 + - 0.17	< 0.60
Mo- 99	< 5.2	< 2.2	< 3.1
Sb-122	0.393 + - 0.074	0.280 + - 0.046	0.187 + - 0.046
La-140	3.55 + - 0.20	7.75 + - 0.34	8.44 + - 0.35
Sm-153	0.574 + - 0.029	1.519 + - 0.071	1.425 + - 0.071
Yb-175	< 0.32	0.617 + - 0.054	1.177 + - 0.080
Lu-177	< 0.050	0.132 + - 0.013	0.223 + - 0.018
W -187	< 1.22	< 0.46	< 0.99
Au-198	0.0239 + - 0.0029	< 0.0028	< 0.0048
Sc- 46	0.579 + - 0.024	1.727 + - 0.067	1.708 + - 0.067
Cr- 51	3.02 + - 0.50	12.88 + - 0.95	18.9 + - 1.1
Fe- 59	2820 + - 140	3020 + - 140	2220 + - 110
Co- 60	1.73 + - 0.11	1.79 + - 0.11	1.235 + - 0.082
Zn- 65	10.8 + - 3.4	13.2 + - 3.3	39.6 + - 4.7
Se- 75	< 0.77	< 1.7	< 1.9
Rb- 86	< 6.4	16.2 + - 3.1	40.8 + - 3.8
Zr- 95	< 61	< 56	254 + - 30
Ag-110	< 0.60	< 0.70	< 0.74
Cs-134	< 0.161	1.03 + - 0.10	1.23 + - 0.11
Ba-131	239 + - 34	518 + - 48	545 + - 46
Ce-141	6.07 + - 0.39	15.20 + - 0.74	17.04 + - 0.73
Nd-147	< 10.9	< 8.5	< 9.2
Eu-152	0.100 + - 0.022	0.320 + - 0.036	0.356 + - 0.034
Tb-160	0.117 + - 0.042	0.206 + - 0.041	0.169 + - 0.036
Hf-181	0.914 + - 0.066	1.805 + - 0.097	8.15 + - 0.28
Ta-182	< 0.226	< 0.182	0.267 + - 0.052
Hg-203	< 0.30	< 0.32	< 0.36
Th-233	0.950 + - 0.066	2.67 + - 0.12	2.37 + - 0.10

	6201310	6201320	6201330
Na- 24	196 + 14	291 + 19	232 + 16
Mg- 27	< 570	5460 + 480	1150 + 240
Al- 28	10320 + 530	15840 + 740	18320 + 810
Cl- 38	< 76	39 + 12	< 16
Ca- 49	1250 + - 330	23600 + - 1700	< 320
Ti- 51	1320 + - 110	500 + - 110	1120 + - 92
V - 52	15.0 + - 1.4	13.5 + - 1.8	22.8 + - 1.7
Mn- 56	129.0 + - 4.6	270.6 + - 9.5	145.2 + - 5.1
Cu- 66	< 74	< 85	< 80
Sr- 87	< 110	243 + 58	< 110
In-116	< 0.051	< 0.061	< 0.054
I -128	< 6.8	< 8.5	< 6.9
Ba-139	173 + - 24	4380 + - 230	182 + - 18
Dy-165	0.53 + - 0.12	0.99 + - 0.14	0.785 + - 0.096
U -235	0.839 + - 0.023	0.428 + - 0.012	0.852 + - 0.024
K - 42	6920 + - 680	8320 + - 750	9250 + - 780
Ga- 72	< 4.5	< 3.8	< 4.3
As- 76	1.04 + - 0.15	1.08 + - 0.17	2.10 + - 0.22
Br- 82	< 0.41	< 0.44	0.37 + - 0.11
Mo- 99	< 3.1	< 2.2	< 2.3
Sb-122	0.277 + - 0.040	0.180 + - 0.035	0.374 + - 0.039
La-140	4.35 + - 0.22	5.37 + - 0.25	6.30 + - 0.28
Sm-153	0.479 + - 0.026	< 0.012	0.669 + - 0.034
Yb-175	0.690 + - 0.057	0.457 + - 0.044	0.767 + - 0.051
Lu-177	0.104 + - 0.012	0.046 + - 0.018	0.155 + - 0.012
W -187	< 0.68	< 0.49	< 0.67
Au-198	0.0315 + - 0.0027	0.0059 + - 0.0013	0.0243 + - 0.0022
Sc- 46	1.314 + - 0.053	1.099 + - 0.044	1.752 + - 0.068
Cr- 51	16.2 + - 1.1	9.11 + - 0.76	15.5 + - 1.0
Fe- 59	4580 + - 200	3080 + - 140	5350 + - 220
Co- 60	1.212 + - 0.097	1.58 + - 0.10	2.38 + - 0.13
Zn- 65	< 3.9	6.1 + 2.8	46.5 + 5.2
Se- 75	< 2.1	< 1.7	< 1.8
Rb- 86	19.2 + - 3.3	31.5 + 3.6	42.2 + 4.3
Zr- 95	225 + - 36	< 48	229 + 32
Ag-110	< 0.66	< 0.58	< 0.59
Cs-134	0.80 + - 0.10	0.922 + - 0.090	1.14 + - 0.10
Ba-131	153 + - 42	4460 + - 180	242 + - 35
Ce-141	8.44 + - 0.55	10.45 + - 0.63	14.80 + - 0.65
Nd-147	< 15	< 8.2	< 8.9
Eu-152	0.125 + 0.024	0.243 + 0.031	0.215 + 0.029
Tb-160	< 0.130	< 0.074	0.115 + 0.027
Hf-181	7.11 + - 0.26	2.98 + - 0.13	6.70 + - 0.23
Ta-182	0.165 + - 0.048	0.151 + - 0.051	0.232 + - 0.042
Hg-203	< 0.43	< 0.30	< 0.35
Th-233	1.579 + - 0.093	1.711 + - 0.092	2.73 + - 0.11

	6201340	6201350	6201360
Na- 24	2154 ± 73	316 ± 20	346 ± 21
Mg- 27	4760 ± 500	14980 ± 880	8930 ± 650
Al- 28	22730 ± 930	11530 ± 610	8340 ± 490
Cl- 38	65 ± 16	56 ± 12	< 36
Ca- 49	21200 ± 1600	29200 ± 2100	21300 ± 1700
Ti- 51	920 ± 110	422 ± 88	< 460
V - 52	74.5 ± 3.9	20.9 ± 1.8	14.8 ± 2.0
Mn- 56	186.8 ± 6.5	386 ± 14	687 ± 23
Cu- 66	< 130	< 95	< 140
Sr- 87	< 140	< 150	< 220
In-116	< 0.077	< 0.069	< 0.101
I -128	< 9.2	< 9.7	< 15
Ba-139	271 ± 27	1215 ± 70	< 83
Dy-165	0.80 ± 0.13	0.86 ± 0.13	0.99 ± 0.17
U -235	2.159 ± 0.060	0.502 ± 0.014	0.3300 ± 0.0092
K - 42	14600 ± 1100	9820 ± 810	7000 ± 1400
Ga- 72	< 8.9	< 3.7	< 11.2
As- 76	1.46 ± 0.24	0.557 ± 0.100	1.20 ± 0.20
Br- 82	< 0.75	< 0.32	< 0.54
Mo- 99	< 4.8	< 2.1	< 2.5
Sb-122	< 0.15	0.117 ± 0.033	0.164 ± 0.044
La-140	9.33 ± 0.40	5.76 ± 0.27	5.78 ± 0.30
Sm-153	1.307 ± 0.065	< 0.011	0.952 ± 0.052
Yb-175	0.711 ± 0.066	0.550 ± 0.051	0.479 ± 0.051
Lu-177	0.143 ± 0.021	< 0.018	0.0816 ± 0.0086
W -187	< 1.24	< 0.48	< 0.91
Au-198	< 0.0059	0.0384 ± 0.0030	< 0.0034
Sc- 46	2.286 ± 0.089	1.058 ± 0.042	0.989 ± 0.040
Cr- 51	14.2 ± 1.2	8.39 ± 0.68	5.26 ± 0.53
Fe- 59	4160 ± 190	2400 ± 120	2650 ± 120
Co- 60	6.21 ± 0.29	1.437 ± 0.095	3.04 ± 0.16
Zn- 65	< 3.5	9.6 ± 2.9	33.3 ± 4.6
Se- 75	< 1.18	< 0.59	< 0.62
Rb- 86	45.3 ± 5.2	27.8 ± 3.5	12.2 ± 2.2
Zr- 95	202 ± 52	103 ± 24	< 82
Ag-110	< 1.08	< 0.55	< 0.67
Cs-134	1.35 ± 0.13	0.525 ± 0.067	0.561 ± 0.079
Ba-131	387 ± 52	1298 ± 73	62 ± 14
Ce-141	17.73 ± 0.96	10.75 ± 0.59	10.39 ± 0.49
Nd-147	< 17	< 7.2	< 4.0
Eu-152	0.306 ± 0.039	0.242 ± 0.033	0.212 ± 0.030
Tb-160	0.260 ± 0.044	0.136 ± 0.032	0.180 ± 0.050
Hf-181	4.14 ± 0.17	3.38 ± 0.14	0.894 ± 0.058
Ta-182	0.232 ± 0.064	< 0.158	< 0.189
Hg-203	< 0.49	< 0.27	< 0.26
Th-233	2.94 ± 0.14	1.370 ± 0.078	1.202 ± 0.064

	6201370	6201380	6201410
Na- 24	908 ± 41	631 ± 29	173 ± 13
Mg- 27	1450 ± 360	4280 ± 470	2010 ± 260
Al- 28	11880 ± 640	16800 ± 760	11640 ± 570
Cl- 38	< 52	60 ± 12	28.3 ± 8.1
Ca- 49	87000 ± 4300	6010 ± 850	4580 ± 690
Ti- 51	< 520	670 ± 100	390 ± 78
V - 52	31.1 ± 2.8	471 ± 17	28.2 ± 2.0
Mn- 56	707 ± 24	193.9 ± 6.8	81.8 ± 2.9
Cu- 66	< 170	491 ± 88	< 61
Sr- 87	< 250	< 120	< 85
In-116	< 0.116	< 0.069	< 0.044
I -128	< 16	< 7.9	< 5.6
Ba-139	177 ± 43	202 ± 22	129 ± 18
Dy-165	1.08 ± 0.23	0.73 ± 0.11	0.55 ± 0.10
U -235	18.02 ± 0.50	9.39 ± 0.26	0.526 ± 0.015
K - 42	11400 ± 1800	11900 ± 1800	7800 ± 1500
Ga- 72	< 16	< 12.3	< 12.5
As- 76	3.86 ± 0.48	12.0 ± 1.0	< 0.58
Br- 82	< 0.81	< 0.57	< 0.60
Mo- 99	1.77 ± 0.13	8.99 ± 0.71	< 3.7
Sb-122	0.215 ± 0.054	0.280 ± 0.058	0.163 ± 0.034
La-140	9.82 ± 0.47	7.99 ± 0.40	4.64 ± 0.28
Sm-153	1.47 ± 0.17	0.84 ± 0.11	0.556 ± 0.042
Yb-175	0.88 ± 0.11	0.619 ± 0.074	0.432 ± 0.063
Lu-177	< 0.14	< 0.092	0.090 ± 0.016
W -187	< 1.36	< 1.03	< 1.07
Au-198	< 0.0053	< 0.0040	< 0.0039
Sc- 46	0.952 ± 0.040	1.399 ± 0.056	0.829 ± 0.035
Cr- 51	6.10 ± 0.72	8.27 ± 0.77	5.64 ± 0.72
Fe- 59	1532 ± 95	2090 ± 110	1970 ± 110
Co- 60	0.482 ± 0.077	2.76 ± 0.16	1.25 ± 0.11
Zn- 65	< 3.2	15.2 ± 3.9	< 1.3
Se- 75	< 2.4	4.18 ± 0.80	< 0.99
Rb- 86	24.8 ± 3.4	36.0 ± 3.7	20.7 ± 3.2
Zr- 95	48.7 ± 8.5	109 ± 18	< 72
Ag-110	< 0.84	18.7 ± 1.8	< 0.81
Cs-134	0.71 ± 0.12	0.98 ± 0.11	0.76 ± 0.11
Ba-131	145 ± 16	182 ± 20	119 ± 26
Ce-141	20.25 ± 0.93	12.69 ± 0.62	7.94 ± 0.60
Nd-147	< 8.9	12.4 ± 3.3	< 7.7
Eu-152	0.363 ± 0.053	0.210 ± 0.032	0.168 ± 0.037
Tb-160	0.192 ± 0.039	0.201 ± 0.047	< 0.39
Hf-181	2.99 ± 0.15	2.98 ± 0.13	1.309 ± 0.090
Ta-182	< 0.27	< 0.232	< 0.261
Hg-203	< 0.40	< 0.25	< 0.35
Th-233	1.231 ± 0.084	2.23 ± 0.10	1.340 ± 0.088

	6201430	6201440	6201450
Na- 24	945 + - 38	308 + - 18	505 + - 25
Mg- 27	1960 + - 320	2170 + - 360	3220 + - 350
Al- 28	13450 + - 650	9030 + - 510	13800 + - 660
Cl- 38	< 23	30.0 + - 9.7	< 30
Ca- 49	< 280	14700 + - 1300	31800 + - 2200
Ti- 51	709 + - 89	< 210	< 280
V - 52	155.2 + - 6.5	636 + - 22	35.0 + - 2.3
Mn- 56	136.5 + - 4.9	119.8 + - 4.3	236.6 + - 8.3
Cu- 66	< 100	< 100	< 100
Sr- 87	< 120	< 100	< 140
In-116	< 0.065	< 0.061	< 0.069
I -128	< 7.8	< 6.5	< 8.9
Ba-139	249 + - 26	126 + - 23	217 + - 23
Dy-165	0.79 + - 0.15	< 0.30	0.92 + - 0.11
U -235	2.298 + - 0.064	3.373 + - 0.094	7.93 + - 0.22
K - 42	12410 + - 810	4630 + - 360	8480 + - 580
Ga- 72	< 4.2	< 2.1	< 3.0
As- 76	2.75 + - 0.26	1.18 + - 0.14	21.3 + - 1.6
Br- 82	< 0.54	< 0.30	< 0.40
Mo- 99	< 3.9	< 2.0	3.32 + - 0.22
Sb-122	0.285 + - 0.039	0.248 + - 0.032	0.773 + - 0.057
La-140	5.74 + - 0.26	9.00 + - 0.36	5.90 + - 0.26
Sm-153	0.939 + - 0.055	0.589 + - 0.037	1.194 + - 0.084
Yb-175	0.524 + - 0.058	0.331 + - 0.058	0.515 + - 0.054
Lu-177	0.095 + - 0.025	< 0.051	< 0.098
W -187	< 0.67	< 0.41	< 0.55
Au-198	0.0276 + - 0.0026	0.0288 + - 0.0024	0.1406 + - 0.0087
Sc- 46	1.362 + - 0.054	0.843 + - 0.035	1.047 + - 0.042
Cr- 51	3.48 + - 0.69	4.87 + - 0.67	6.07 + - 0.58
Fe- 59	2480 + - 120	1735 + - 95	3170 + - 150
Co- 60	3.02 + - 0.15	4.06 + - 0.20	3.60 + - 0.18
Zn- 65	39.6 + - 4.7	45.2 + - 6.0	44.0 + - 5.6
Se- 75	< 1.4	< 0.64	< 0.62
Rb- 86	43.0 + - 4.1	14.2 + - 3.0	25.3 + - 3.4
Zr- 95	118 + - 20	< 71	49.2 + - 8.7
Ag-110	< 0.70	< 0.69	< 0.80
Cs-134	0.889 + - 0.088	0.509 + - 0.080	1.09 + - 0.11
Ba-131	203 + - 26	< 350	163 + - 21
Ce-141	11.53 + - 0.58	12.16 + - 0.67	12.11 + - 0.62
Nd-147	< 7.5	< 11.5	< 7.3
Eu-152	0.301 + - 0.034	0.115 + - 0.023	0.269 + - 0.034
Tb-160	0.141 + - 0.070	< 0.078	< 0.13
Hf-181	2.90 + - 0.12	0.891 + - 0.069	2.122 + - 0.100
Ta-182	0.162 + - 0.047	< 0.300	< 0.180
Hg-203	< 0.32	< 0.34	< 0.28
Th-233	1.754 + - 0.082	1.441 + - 0.084	1.610 + - 0.089

	6201460	6201470	6201480
Na- 24	108 + - 11	2602 + - 88	2506 + - 83
Mg- 27	3240 + - 340	6190 + - 820	3460 + - 440
Al- 28	8890 + - 460	12890 + - 700	11050 + - 600
Cl- 38	< 18	4440 + 250	1770 + - 110
Ca- 49	9510 + 960	29400 + 2100	46400 + - 2800
Ti- 51	706 + 99	500 + 110	500 + - 120
V - 52	157.8 + - 6.5	935 + - 33	28.9 + - 2.1
Mn- 56	141.1 + - 4.9	180.1 + - 6.5	208.8 + - 7.3
Cu- 66	< 83	< 180	< 120
Sr- 87	< 110	< 160	< 140
In-116	< 0.056	< 0.104	< 0.081
I -128	< 7.0	< 10.3	< 9.1
Ba-139	< 49	1192 + - 73	419 + - 31
Dy-165	0.58 + - 0.12	1.37 + - 0.19	0.63 + - 0.10
U -235	1.329 ∓ - 0.037	65.3 ∓ - 1.8	2.129 + - 0.060
K - 42	2710 + - 290	7310 + - 590	7300 + - 550
Ga- 72	< 2.3	< 5.1	< 5.1
As- 76	3.23 + - 0.28	30.3 + - 2.3	10.36 + - 0.80
Br- 82	< 0.30	20.7 + 1.6	2.34 + - 0.25
Mo- 99	< 2.5	23.15 ∓ 0.88	3.42 + - 0.40
Sb-122	0.150 + - 0.025	1.097 + - 0.082	0.501 + - 0.060
La-140	4.33 + - 0.20	6.95 + - 0.29	4.94 + - 0.22
Sm-153	0.587 + - 0.036	< 1.2	0.877 + - 0.050
Yb-175	0.519 + - 0.045	0.357 + - 0.089	0.503 + - 0.071
Lu-177	0.085 + 0.013	< 0.14	< 0.055
W -187	< 0.43	< 0.72	< 0.69
Au-198	0.0092 + - 0.0015	< 0.0060	< 0.0052
Sc- 46	0.865 + - 0.035	0.977 + - 0.040	0.939 + - 0.038
Cr- 51	37.7 + - 1.9	8.51 + - 0.95	7.42 + - 0.64
Fe- 59	2690 + - 120	3750 + - 180	2770 + - 130
Co- 60	1.229 + - 0.079	8.44 + - 0.38	1.311 + - 0.088
Zn- 65	30.8 + - 3.7	34.8 + - 5.6	15.5 + - 3.2
Se- 75	1.13 + 0.29	6.2 + 1.1	5.09 + - 0.90
Rb- 86	10.4 + 2.0	18.7 + 3.3	28.0 + - 4.1
Zr- 95	162 + - 22	85.3 + - 8.4	120 + 19
Ag-110	< 0.42	< 0.74	< 0.53
Cs-134	0.383 + 0.057	0.94 + 0.11	0.621 + - 0.071
Ba-131	77 + 18	1198 + 82	330 + - 33
Ce-141	9.05 ∓ - 0.43	20.23 ∓ - 0.91	8.61 + - 0.50
Nd-147	< 6.8	< 17	< 6.8
Eu-152	0.168 + 0.024	0.294 + - 0.042	0.224 + 0.029
Tb-160	0.144 + 0.030	< 0.14	< 0.065
Hf-181	3.86 + 0.15	2.36 + - 0.12	2.41 + 0.11
Ta-182	0.115 + 0.029	< 0.32	< 0.157
Hg-203	< 0.27	< 0.43	< 0.13
Th-233	1.355 + - 0.068	1.48 + - 0.10	1.173 + - 0.069

	6201500	6201510	6201520
Na- 24	431 + - 25	218 + - 14	1513 + - 56
Mg- 27	2540 + - 440	1630 + - 230	3240 + - 480
Al- 28	10830 + - 620	9670 + - 500	24600 + - 1000
Cl- 38	< 41	53.4 + - 8.4	< 37
Ca- 49	89600 + - 4400	4740 + - 700	37600 + - 2400
Ti- 51	500 + - 130	322 + - 47	800 + - 130
V - 52	15.9 + - 2.1	28.4 + - 2.0	132.7 + - 6.0
Mn- 56	735 + - 25	53.6 + - 2.0	203.2 + - 7.1
Cu- 66	< 130	< 59	< 130
Sr- 87	< 210	< 70	< 160
In-116	< 0.094	< 0.038	< 0.083
I -128	< 14	< 4.5	< 9.9
Ba-139	2920 + - 160	< 32	336 + - 38
Dy-165	1.08 + - 0.14	0.646 + - 0.074	0.94 + - 0.16
U -235	1.037 + - 0.029	0.769 + - 0.022	7.51 + - 0.21
K - 42	6810 + - 500	1840 + - 250	17700 + - 1100
Ga- 72	< 2.6	< 2.2	< 5.8
As- 76	0.75 + - 0.14	0.70 + - 0.10	1.77 + - 0.21
Br- 82	< 0.43	0.89 + - 0.12	< 0.89
Mo- 99	< 2.3	< 1.9	3.73 + - 0.41
Sb-122	0.209 + - 0.029	0.149 + - 0.024	0.265 + - 0.061
La-140	10.21 + - 0.40	5.23 + - 0.24	9.51 + - 0.40
Sm-153	1.514 + - 0.071	0.781 + - 0.039	1.436 + - 0.088
Yb-175	0.934 + - 0.062	0.377 + - 0.039	0.97 + - 0.10
Lu-177	0.152 + - 0.015	0.092 + - 0.011	0.155 + - 0.062
W -187	< 0.43	< 0.33	< 1.01
Au-198	< 0.0029	< 0.0026	< 0.0060
Sc- 46	1.096 + - 0.044	0.871 + - 0.036	2.121 + - 0.083
Cr- 51	15.3 + - 1.1	11.41 + - 0.79	12.01 + - 0.90
Fe- 59	3030 + - 140	983 + - 63	3170 + - 140
Co- 60	1.238 + - 0.090	0.803 + - 0.069	1.279 + - 0.088
Zn- 65	< 3.9	7.1 + - 2.6	37.5 + - 5.1
Se- 75	< 2.0	< 1.3	< 1.7
Rb- 86	27.1 + - 3.6	9.5 + - 2.0	54.0 + - 4.7
Zr- 95	182 + - 27	< 48	82 + - 15
Ag-110	< 0.75	< 0.49	1.93 + - 0.64
Cs-134	0.979 + - 0.099	0.541 + - 0.074	1.49 + - 0.13
Ba-131	2910 + - 130	< 87	245 + - 29
Ce-141	21.7 + - 1.0	10.06 + - 0.52	21.60 + - 0.95
Nd-147	< 15	< 6.1	< 9.4
Eu-152	0.358 + - 0.040	0.164 + - 0.026	0.424 + - 0.041
Tb-160	0.356 + - 0.062	0.110 + - 0.033	0.349 + - 0.078
Hf-181	6.23 + - 0.23	1.474 + - 0.078	3.78 + - 0.15
Ta-182	0.190 + - 0.059	< 0.160	0.313 + - 0.060
Hg-203	< 0.41	< 0.24	< 0.38
Th-233	1.506 + - 0.092	1.441 + - 0.075	2.73 + - 0.12

	6201530			6201540			6201550		
Na- 24	454	+ -	24	297	+ -	20	698	+ -	29
Mg- 27	3660	+ -	380		<	1200	1720	+ -	290
Al- 28	24700	+ -	1000	13570	+ -	730	12080	∓ -	580
Cl- 38		<	20		<	45	87	+ -	11
Ca- 49	23600	+ -	1800	73200	+ -	4000	1340	+ -	290
Ti- 51	1080	+ -	110	1580	+ -	160	892	+ -	84
V - 52	73.6	+ -	3.9	14.2	+ -	2.3	156.7	+ -	6.4
Mn- 56	166.0	+ -	5.8	648	+ -	23	57.5	+ -	2.1
Cu- 66		<	86		<	150		<	82
Sr- 87		<	110		<	230		<	82
In-116		<	0.058		<	0.107		<	0.050
I -128		<	7.1		<	15		<	5.4
Ba-139	248	+ -	25	228	+ -	29	121	+ -	16
Dy-165	1.52	+ -	0.15	1.23	+ -	0.17	0.47	+ -	0.13
U -235	1.801	+ -	0.050	0.877	+ -	0.025	2.428	+ -	0.068
K - 42	17500	+ -	1000	8400	+ -	610	4040	+ -	410
Ga- 72	5.2	+ -	1.3		<	3.0		<	3.8
As- 76	1.46	+ -	0.17	0.89	+ -	0.13	1.56	+ -	0.17
Br- 82		<	0.39	0.51	+ -	0.15	1.11	+ -	0.35
Mo- 99		<	2.4		<	2.4		<	3.7
Sb-122	0.186	+ -	0.036	0.231	+ -	0.046	0.172	+ -	0.036
La-140	9.40	+ -	0.39	6.98	+ -	0.30	5.00	+ -	0.23
Sm-153	1.470	+ -	0.069	1.042	+ -	0.051	0.622	+ -	0.036
Yb-175	0.892	+ -	0.066	1.009	+ -	0.062	0.764	+ -	0.063
Lu-177	0.142	+ -	0.016	0.191	+ -	0.013	0.136	+ -	0.018
W -187	0.65	+ -	0.16		<	0.50		<	0.58
Au-198		<	0.0034	0.0541	+ -	0.0037	0.0146	+ -	0.0019
Sc- 46	2.338	+ -	0.091	1.259	∓ -	0.050	0.919	∓ -	0.037
Cr- 51	14.8	+ -	1.1	26.0	+ -	1.5	254	+ -	11
Fe- 59	3980	+ -	180	4490	+ -	190	1189	+ -	67
Co- 60	1.92	+ -	0.13	0.931	+ -	0.074	0.993	+ -	0.071
Zn- 65		<	6.8	6.3	+ -	3.0	40.4	+ -	4.5
Se- 75		<	1.23		<	1.8		<	1.3
Rb- 86	52.0	+ -	5.5	23.3	+ -	3.1	13.7	+ -	2.3
Zr- 95	164	+ -	34	425	+ -	45	349	+ -	36
Ag-110		<	1.08		<	0.58		<	0.52
Cs-134	1.98	+ -	0.17	0.793	+ -	0.096	0.637	+ -	0.073
Ba-131	312	+ -	64	236	+ -	30	129	+ -	22
Ce-141	18.82	+ -	0.94	11.73	+ -	0.67	9.69	+ -	0.49
Nd-147		<	17		<	9.1		<	8.4
Eu-152	0.334	+ -	0.041	0.257	+ -	0.031	0.173	+ -	0.025
Tb-160	0.276	+ -	0.073		<	0.13		<	0.090
Hf-181	5.31	+ -	0.21	11.99	+ -	0.40	9.96	+ -	0.33
Ta-182	0.350	+ -	0.066	0.272	+ -	0.064	0.162	+ -	0.047
Hg-203		<	0.51		<	0.33		<	0.32
Th-233	2.98	+ -	0.14	2.09	+ -	0.10	1.919	+ -	0.092

	6201570	6201590	6201600
Na- 24	346 + - 19	827 + - 37	255 + - 16
Mg- 27	1180 + - 260	3090 + - 490	2890 + - 350
Al- 28	14350 ∓ - 670	13900 + - 740	10480 + - 540
Cl- 38	34.9 + - 9.7	< 45	< 18
Ca- 49	< 260	101000 + - 4900	4000 + - 660
Ti- 51	617 + - 80	< 470	543 + - 98
V - 52	129.1 + - 5.7	13.8 + - 2.7	161.6 ∓ - 6.6
Mn- 56	143.6 + - 5.0	815 + - 28	155.8 + - 5.5
Cu- 66	< 90	< 150	401 + - 75
Sr- 87	< 110	< 220	< 120
In-116	< 0.059	< 0.103	< 0.061
I -128	< 7.2	< 15	< 7.7
Ba-139	198 + - 19	254 + - 41	110 + - 20
Dy-165	0.83 + - 0.10	1.35 + - 0.18	0.307 + - 0.075
U -235	2.548 ∓ - 0.071	0.950 + - 0.027	15.84 + - 0.44
K - 42	9750 + - 660	10890 + - 730	6830 + - 540
Ga- 72	< 3.0	< 3.4	< 3.2
As- 76	5.01 + - 0.41	0.64 + - 0.12	80.1 + - 5.9
Br- 82	< 0.36	< 0.39	< 0.41
Mo- 99	0.218 + - 0.033	< 2.4	17.58 + - 0.81
Sb-122	0.161 + - 0.027	0.210 + - 0.042	< 0.088
La-140	6.24 + - 0.27	10.21 + - 0.41	5.98 + - 0.26
Sm-153	1.070 + - 0.057	1.634 + - 0.075	0.70 + - 0.22
Yb-175	0.588 + - 0.048	0.748 + - 0.066	0.302 + - 0.048
Lu-177	0.083 + - 0.017	< 0.023	< 0.076
W -187	< 0.52	< 0.57	< 0.54
Au-198	< 0.0031	0.0165 + - 0.0018	< 0.0043
Sc- 46	1.339 + - 0.054	1.259 + - 0.050	0.825 + - 0.034
Cr- 51	10.86 + - 0.79	9.02 + - 0.82	6.04 + - 0.65
Fe- 59	3160 + - 140	3380 + - 160	2460 + - 120
Co- 60	1.91 + - 0.11	1.380 + - 0.098	14.15 + - 0.58
Zn- 65	8.8 + - 2.9	9.6 + - 3.3	53.0 + - 6.4
Se- 75	< 2.0	< 1.2	< 0.64
Rb- 86	33.9 + - 3.9	34.4 + - 4.3	17.4 + - 3.2
Zr- 95	74 + - 19	< 71	66.9 + - 9.5
Ag-110	< 0.48	< 0.81	2.49 + - 0.30
Cs-134	0.756 + - 0.080	1.26 + - 0.12	0.598 + - 0.076
Ba-131	229 + - 29	338 + - 46	55.6 + - 6.2
Ce-141	13.43 + - 0.68	19.97 + - 1.00	10.43 + - 0.52
Nd-147	< 7.1	< 14	< 7.6
Eu-152	0.303 + - 0.035	0.431 + - 0.045	0.160 + - 0.026
Tb-160	0.093 + - 0.030	0.244 + - 0.053	< 0.146
Hf-181	2.62 + - 0.12	3.01 ∓ - 0.14	1.809 + - 0.096
Ta-182	< 0.173	0.212 + - 0.063	< 0.230
Hg-203	< 0.29	< 0.40	< 0.30
Th-233	1.635 + - 0.087	1.614 + - 0.094	1.684 + - 0.091

	6201610	6201620	6201630
Na- 24	622 + - 29	261 + - 19	1057 + - 41
Mg- 27	5250 + - 570	6080 + - 500	1940 + - 320
Al- 28	17360 + - 780	9870 + - 570	14850 + - 700
Cl- 38	< 33	< 26	< 25
Ca- 49	30900 + - 2100	37300 + - 2400	2840 + - 540
Ti- 51	600 + - 120	< 310	720 + - 110
V - 52	236.4 + - 9.2	31.9 + - 2.2	14.6 + - 1.7
Mn- 56	277.0 + - 9.7	388 + - 14	127.8 + - 4.6
Cu- 66	< 130	< 94	< 91
Sr- 87	< 160	< 150	< 110
In-116	< 0.087	< 0.069	< 0.059
I -128	< 11	< 9.8	< 7.0
Ba-139	151 + - 29	< 60	274 + - 23
Dy-165	0.98 + - 0.18	< 0.41	0.546 + - 0.074
U -235	58.2 + - 1.6	5.28 + - 0.15	0.533 + - 0.015
K - 42	8990 + - 690	7070 + - 520	12220 + - 830
Ga- 72	< 4.4	< 2.6	< 4.4
As- 76	27.3 + - 2.0	3.92 + - 0.34	1.39 + - 0.17
Br- 82	< 0.55	< 0.29	< 0.47
Mo- 99	23.4 + - 1.0	< 2.0	< 2.6
Sb-122	0.808 + - 0.070	0.249 + - 0.033	0.162 + - 0.032
La-140	6.72 + - 0.30	5.07 + - 0.23	5.31 + - 0.24
Sm-153	< 1.2	0.941 + - 0.058	0.637 + - 0.039
Yb-175	0.810 + - 0.075	0.472 + - 0.042	0.525 + - 0.056
Lu-177	< 0.16	0.100 + - 0.038	0.057 + - 0.019
W -187	< 0.77	< 0.43	< 0.60
Au-198	< 0.0050	0.0199 + - 0.0018	< 0.0039
Sc- 46	1.330 + - 0.053	0.839 + - 0.034	1.133 + - 0.045
Cr- 51	12.52 + - 0.88	7.16 + - 0.76	8.57 + - 0.74
Fe- 59	4930 + - 210	6980 + - 290	3880 + - 170
Co- 60	1.185 + - 0.081	1.46 + - 0.10	1.74 + - 0.11
Zn- 65	73.0 + - 7.5	< 0.38	10.9 + - 2.9
Se- 75	2.01 + - 0.44	< 1.5	< 1.6
Rb- 86	27.9 + - 3.4	25.1 + - 3.9	35.4 + - 4.1
Zr- 95	225 + - 20	99 + - 20	56 + - 18
Ag-110	< 0.68	< 0.76	< 0.48
Cs-134	1.12 + - 0.11	0.702 + - 0.090	0.921 + - 0.090
Ba-131	231 + - 13	185 + - 34	167 + - 28
Ce-141	18.24 + - 0.78	11.49 + - 0.88	10.50 + - 0.63
Nd-147	< 9.3	< 12.9	< 7.2
Eu-152	0.358 + - 0.034	0.244 + - 0.034	0.217 + - 0.029
Tb-160	0.247 + - 0.053	< 0.068	< 0.12
Hf-181	6.45 + - 0.23	2.78 + - 0.13	2.71 + - 0.12
Ta-182	0.268 + - 0.060	< 0.251	< 0.188
Hg-203	< 0.37	< 0.38	< 0.28
Th-233	2.162 + - 0.099	1.172 + - 0.076	1.648 + - 0.086

	6201640	6201650	6201670
Na- 24	977 + - 39	552 + - 27	1292 + - 49
Mg- 27	4590 + - 460	6490 + - 560	3920 + - 510
Al- 28	25200 + - 1000	16810 + - 770	14780 + - 710
Cl- 38	190 + - 18	51 + - 13	317 + - 26
Ca- 49	7420 + - 880	30100 + - 2100	28200 + - 2000
Ti- 51	1110 + - 100	740 + - 120	700 + - 100
V - 52	16.2 + - 1.5	27.8 + - 2.2	643 + - 22
Mn- 56	101.1 + - 3.6	258.1 + - 9.0	149.0 + - 5.4
Cu- 66	< 91	< 88	< 150
Sr- 87	< 110	< 130	189 + - 49
In-116	< 0.063	< 0.063	< 0.092
I -128	< 7.0	< 8.4	< 9.6
Ba-139	243 + - 27	217 + - 30	651 + - 46
Dy-165	1.42 + - 0.16	1.05 + - 0.12	< 0.62
U -235	1.343 + - 0.038	0.990 + - 0.028	4.56 + - 0.13
K - 42	14410 + - 970	11830 + - 790	8030 + - 670
Ga- 72	< 5.4	< 3.4	< 5.6
As- 76	1.48 + - 0.21	1.02 + - 0.17	2.91 + - 0.29
Br- 82	0.71 + - 0.19	< 0.38	0.63 + - 0.17
Mo- 99	< 4.2	< 2.4	< 4.4
Sb-122	0.223 + - 0.059	0.242 + - 0.043	0.236 + - 0.046
La-140	9.23 + - 0.39	8.28 + - 0.35	7.16 + - 0.32
Sm-153	1.348 + - 0.067	1.421 + - 0.067	0.844 + - 0.057
Yb-175	1.024 + - 0.083	0.815 + - 0.066	0.672 + - 0.076
Lu-177	0.136 + - 0.018	0.109 + - 0.012	< 0.090
W -187	< 0.76	< 0.58	< 0.82
Au-198	< 0.0051	< 0.0032	< 0.0052
Sc- 46	2.59 + - 0.10	1.752 + - 0.070	1.459 + - 0.058
Cr- 51	16.3 + - 1.1	10.59 + - 0.96	12.52 + - 0.86
Fe- 59	4610 + - 190	4960 + - 210	2220 + - 110
Co- 60	4.45 + - 0.21	2.18 + - 0.14	1.365 + - 0.087
Zn- 65	37.6 + - 4.9	< 7.1	33.3 + - 4.5
Se- 75	2.04 + - 0.50	< 1.8	< 1.6
Rb- 86	49.3 + - 4.5	41.6 + - 4.8	28.4 + - 3.5
Zr- 95	209 + - 36	138 + - 44	121 + - 18
Ag-110	< 0.91	< 0.78	< 0.70
Cs-134	2.32 + - 0.16	1.18 + - 0.12	1.24 + - 0.11
Ba-131	292 + - 39	301 + - 50	689 + - 48
Ce-141	20.66 + - 0.87	17.7 + - 1.0	14.82 + - 0.68
Nd-147	< 9.8	< 16	< 8.5
Eu-152	0.483 + - 0.043	0.331 + - 0.044	0.275 + - 0.033
Tb-160	0.309 + - 0.051	0.278 + - 0.074	0.183 + - 0.043
Hf-181	6.12 + - 0.22	4.52 + - 0.19	4.27 + - 0.16
Ta-182	0.377 + - 0.058	< 0.29	0.196 + - 0.053
Hg-203	< 0.41	< 0.46	< 0.34
Th-233	3.23 + - 0.13	1.82 + - 0.11	1.976 + - 0.095

	U0	U1	U2
Mg- 27	<15000	<4900	<8100
Al- 28	56800 + - 4100	4300 + - 1100	<4200
Cl- 38	<280	<160	<290
Ca- 49	<3700	275000 + - 20000	328000 + - 46000
Ti- 51	<21000	<14000	<17000
V - 52	ND	ND	ND
Mn- 56	196 + - 18	2020 + - 140	2560 + - 180
Cu- 66	<2200	<2450	<1000
Sr- 87	<1200	<830	<960
In-116	<0.86	<0.29	<0.56
I -128	<190	<110	<150
Ba-139	<5900	<11000	1720 + - 250
Dy-165	ND	3.62 + - 0.64	162 + - 20
U -235	7500 + - 340	637 + - 29	1488 + - 67
Na- 24	2090 + - 190	81.4 + - 4.3	198 + - 25
K - 42	<62000	2050 + - 320	1630 + - 270
As- 76	41.8 + - 7.9	1300 + - 140	88 + - 11
Br- 82	<18	1.48 + - 0.43	2.64 + - 0.58
Sb-122	<2.2	32.8 + - 1.6	2.33 + - 0.17
La-140	76.4 + - 7.7	25.8 + - 1.5	17.50 + - 0.91
Sm-153	231 + - 11	<0.85	<1.7
Yb-175	<3.5	1.24 + - 0.25	1.24 + - 0.25
W -187	<60	<2.8	0.35 + - 0.29
Au-198	<0.075	<0.016	<0.0089
Sc- 46	6.03 + - 0.40	0.675 + - 0.053	0.771 + - 0.042
Cr- 51	23.6 + - 6.2	10.6 + - 2.4	6.2 + - 3.3
Fe- 59	25500 + - 1300	10290 + - 570	3290 + - 200
Co- 60	59.3 + - 3.3	44.7 + - 2.4	3.55 + - 0.30
Zn- 65	<32	498 + - 65	870 + - 110
Se- 75	23.3 + - 6.4	430 + - 110	9.8 + - 3.6
Rb- 86	<29	<15	<13
Ag-110	<6.1	3.88 + - 0.66	3.42 + - 0.58
Cs-134	5.41 + - 0.75	<1.0	0.37 + - 0.13
Ce-141	137 + - 32	75 + - 11	259 + - 20
Nd-147	<69	<27	43 + - 23
Eu-152	6.28 + - 0.30	0.457 + - 0.029	0.504 + - 0.076
Tb-160	1.87 + - 0.24	0.356 + - 0.089	0.201 + - 0.071
Lu-177	3.43 + - 0.19	0.594 + - 0.043	1.255 + - 0.068
Hf-181	2.94 + - 0.72	<0.80	1.15 + - 0.33
Ta-182	<1.9	<0.70	<0.82
Th-233	7.9 + - 2.5	1.26 + - 0.17	0.97 + - 0.16

	U3	U4
Mg- 27	ND	<45000
Al- 28	ND	36600 + - 3300
Cl- 38	ND	<570
Ca- 49	ND	<12000
Ti- 51	ND	<45000
V - 52	ND	ND
Mn- 56	ND	130 + - 17
Cu- 66	ND	<4700
Sr- 87	ND	<4100
In-116	ND	<2.7
I -128	ND	<510
Ba-139	ND	<49000
Dy-165	ND	<77
U -235	1900 + - 86	2370 + - 110
Na- 24	2320 + - 110	486 + - 48
K - 42	21600 + - 140	20200 + - 1400
As- 76	51.4 + - 7.3	406 + - 42
Br- 82	1.01 + - 0.55	2.25 + - 0.78
Sb-122	1.52 + - 0.14	10.14 + - 0.55
La-140	32.9 + - 2.0	17.73 + - 0.85
Sm-153	20.0 + - 1.1	<0.51
Yb-175	6.6 + - 4.5	1.45 + - 0.30
W -187	1.29 + - 0.68	2.61 + - 0.57
Au-198	<0.011	0.0484 + - 0.0074
Sc- 46	4.08 + - 0.22	1.75 + - 0.11
Cr- 51	28.7 + - 3.7	58.5 + - 6.3
Fe- 59	14060 + - 750	37400 + - 2000
Co- 60	32.9 + - 1.7	89.1 + - 4.7
Zn- 65	413 + - 55	40 + - 15
Se- 75	4.7 + - 1.5	38.1 + - 9.7
Rb- 86	<13	<25
Ag-110	<3.1	<4.7
Cs-134	5.24 + - 0.35	3.98 + - 0.51
Ce-141	269 + - 19	397 + - 24
Nd-147	64 + - 27	312 + - 47
Eu-152	2.88 + - 0.15	0.91 + - 0.15
Tb-160	1.09 + - 0.11	0.68 + - 0.15
Lu-177	1.556 + - 0.081	1.461 + - 0.091
Hf-181	15.1 + - 1.1	3.02 + - 0.35
Ta-182	2.17 + - 0.97	<1.5
Th-233	3.90 + - 0.21	2.27 + - 0.25

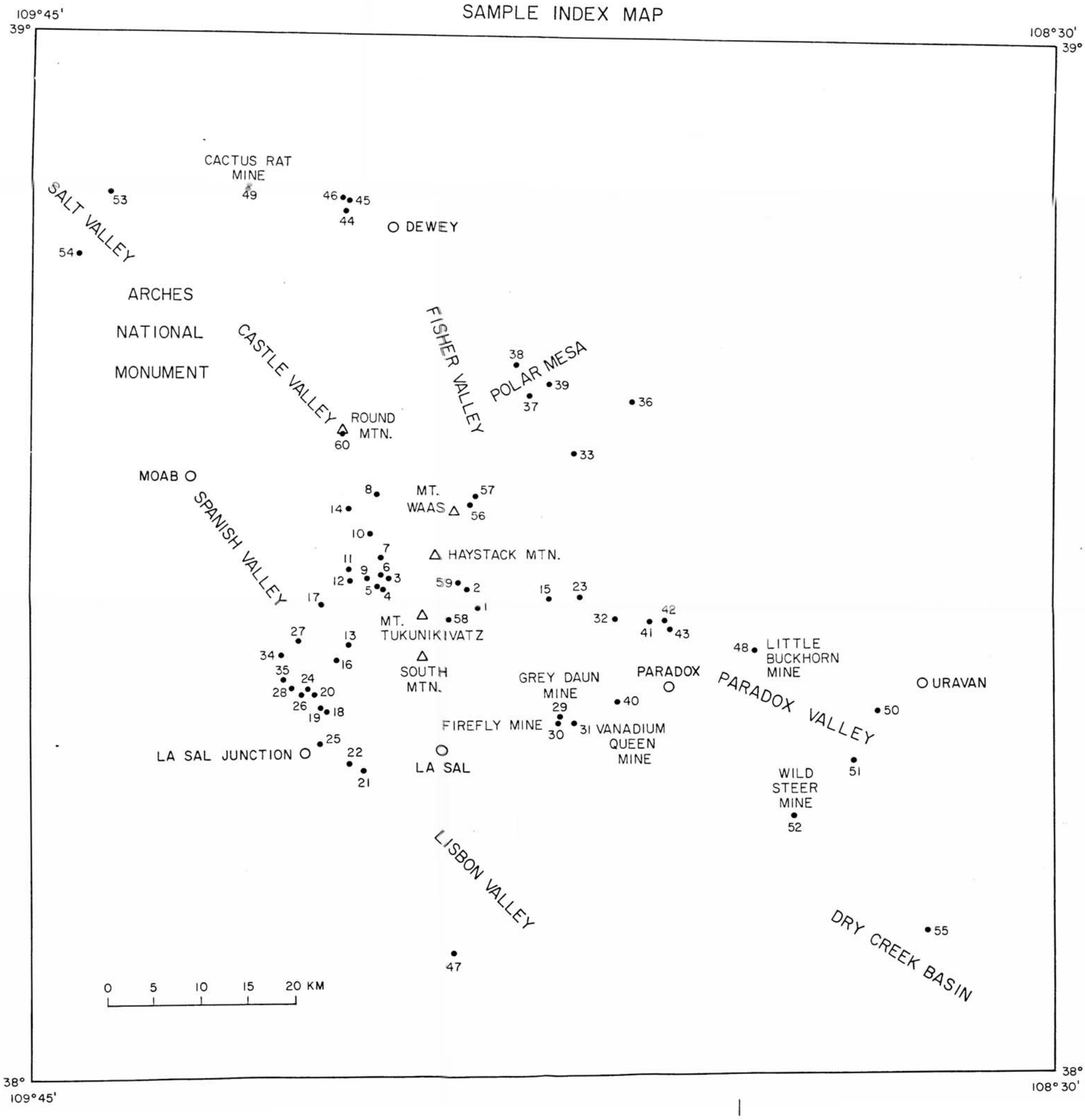
GENERALIZED STRATIGRAPHIC COLUMN FOR THE LA SAL MOUNTAINS AREA

ERATHEM	SYSTEM	SERIES	STRATIGRAPHIC UNIT	DESCRIPTION
CENOZOIC	QUAT.	HOLO.		Undifferentiated alluvium, primarily in the valleys. Thickness varies.
	TERTIARY	PLIOCENE	CASTLE VALLEY & GEYSER CREEK	Conglomerates derived from the northern La Sal Mountains. Thickness varies.
MESOZOIC	CRETACEOUS	UPPER	MANCOS SHALE	Dark gray to black, fissile marine shales. Thickness 0 to 366 meters.
			DAKOTA SANDSTONE	Brown, fluvial sandstones and conglomerates. 61 meters thick.
		LOWER	BURRO CANYON FORMATION	Light-colored, fluvial sandstones and conglomerates. Thickness 76 meters.
	JURASSIC	UPPER	MORRISON FORMATION: BRUSHY BASIN MEMBER	Variegated color, fine-grained lacustrine shales. Thickness 100 to 110 meters.
			MORRISON FORMATION: SALT WASH MEMBER	Interbedded channel sandstones and shales. Thickness 70 to 110 meters.
			SUMMERVILLE FORMATION	Shales and mudstones, variegated color. Thickness 18 to 46 meters.
			ENTRADA SANDSTONE	Light-colored, cross-bedded aeolian sandstones. Thickness 18 to 168 meters.
			CARMEL FORMATION	Siltstones and sandstones. Mapped as part of Entrada Sandstone in La Sal area. Thickness 0 to 20 meters.
	?	?	NAVAJO SANDSTONE	Light-colored, cross-bedded aeolian sandstones. Thickness 122 meters.
	TRIASSIC	UPPER	KAYENTA FORMATION	Interbedded fluvial sandstones, shales and siltstones. Thickness increases from 0 to 73 meters to the west.
			WINGATE SANDSTONE	Light-colored, massive, cliff-forming aeolian sandstones. Thickness increases from 0 to 107 meters to the west
			CHINLE FORMATION: CHURCH ROCK MEMBER	Prominent red-colored beds of sandstone and siltstone. Thickness 114 to 305 meters.
			CHINLE FORMATION: MOSS BACK MEMBER	Basal sandstones and conglomerates. Hosts major uranium deposits in the Lisbon Valley. Thickness 6 to 30 meters.
		LOWER TO MIDDLE	MOENKOPI FORMATION	Chocolate-brown to red-brown shales, siltsones and mudstones. Thickness 0 to 130 meters.
PALEOZOIC	PERMIAN		CUTLER FORMATION	Interbedded red to brown siltstones and sandstones. Thickness 550 meters, maximum.
	--?--		RICO FORMATION	Bedded, fluvial sandstones and siltstones and marine limestones. Thickness 198 meters.
	PENNSYLVANIAN		HERMOSA FORMATION: UPPER MEMBER	Gray to red sandstones, siltstones and marine limestones. Thickness 550 meters.
			HERMOSA FORMATION: PARADOX MEMBER	Interbedded sandstone, limestone, salt, gypsum and anhydrite. Thickness known to be greater than 3350 meters in Paradox Valley (borehole).

Compiled from Wood and Lekas (1958), Williams (1964), and Carter and Gualtieri (1965).

DETAILED STRATIRAPHIC COLUMN FOR THE SALT WASH MEMBER OF THE MORRISON FORMATION

ERATHEM	SYSTEM	SERIES	FORMATION	MEMBER	LITHOLOGY	DESCRIPTION
MESOZOIC	JURASSIC	UPPER	MORRISON FORMATION	BRUSHY BASIN MEMBER		Green, fine grained, montmorillonitic shales and claystones. Top not seen.
				SALT WASH MEMBER		6 meters of light-gray to light-red, medium to coarse grained, cross-bedded sandstones.
						7 meters of red, fine-grained shales or mudstones interbedded with 0.15 to 0.30 meter, light gray, fine-grained sandstone lenses.
						8 meters of light-gray to white, medium to fine-grained, cross-bedded sandstones interbedded with red claystones. Bright-green siltstone or shale appear at cross bed partings, in places. Major producer horizon for uranium in the area. Commonly know as the "third" rim.
						1.2 meters of light-gray to light green, fissile, silty shales.
						10 to 11 meters of red to green, fine-grained shales, mudstones and siltstones interbedded with light-gray to white, fine to medium-grained sandstones
						5 to 6 meters of light-gray to white, fine to medium-grained sandstones. Lenses of red to green claystones present.
						0.8 meters of red, fine-grained claystone. Green colored areas present beneath overlying sandstones.
						5 to 6 meters of light-gray to red, fine to medium-grained sandstones.
						12 meters of red, fine-grained shales and claystones interbedded with two light-gray, medium-grained sandstone beds. Green colored areas lie directly below contact of uranium producing sandstone.
						9 to 11 meters of light-gray, medium to coarse-grained, cross-bedded sandstones.
						2 to 3 meters of red, fine-grained shales and claystones. Red, fine to medium-grained sandstones occur as lenses directly below the above sandstone layer.
						6 meters of light-gray to light-red, fine-grained, cross-bedded sandstones grading downward into light-red to light-gray, fine to medium-grained, limonite stained, cross-bedded sandstones.

PLATE 3

SAMPLE INDEX MAP